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MERAMEC RIVER, MISSOURI COMPREHENSIVE BASIN STUDY. VOLUME III. --ETC(U)

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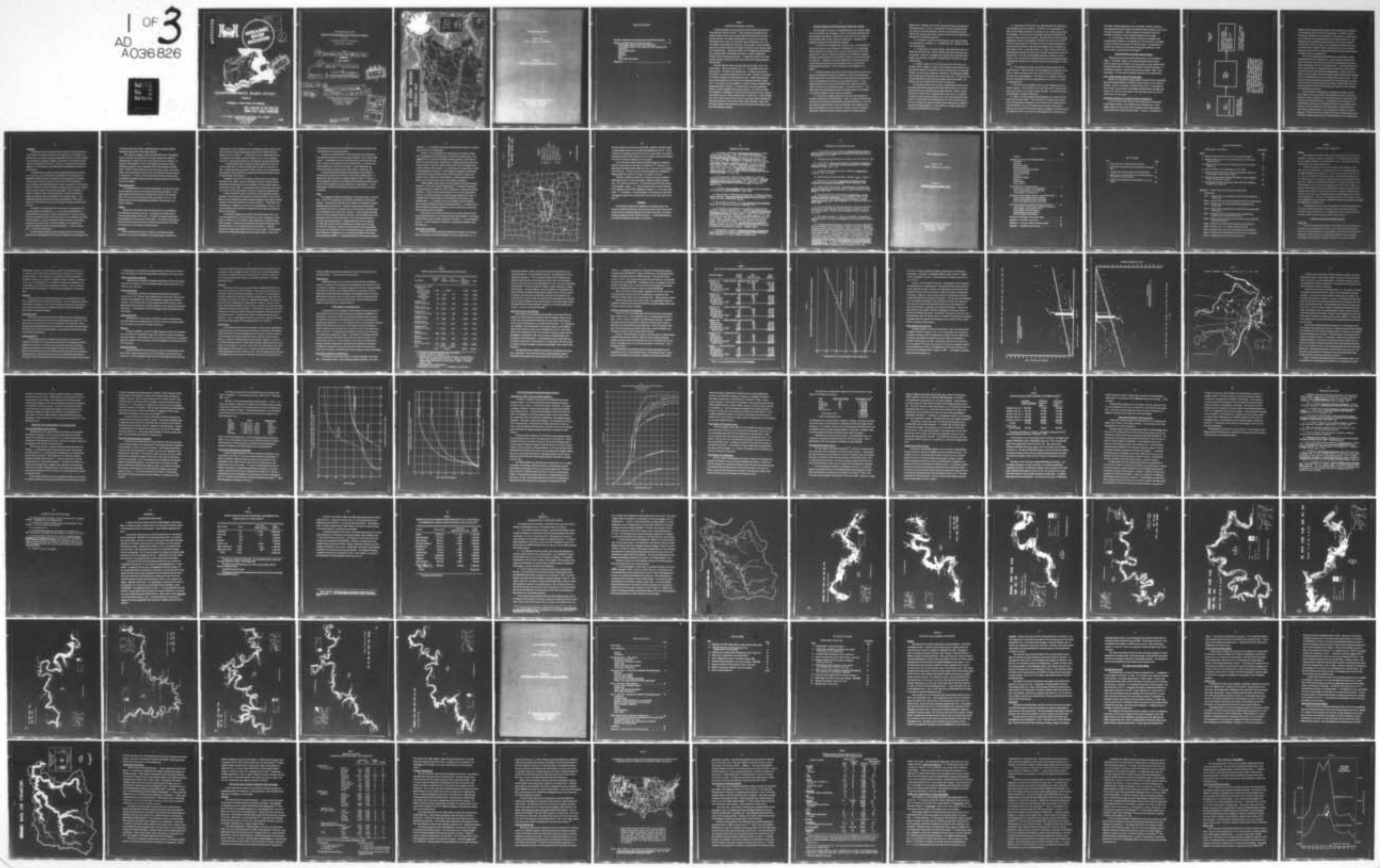

MERAMEC RIVER MISSOURI

COMPREHENSIVE BASIN STUDY

VOLUME III

APPENDIX B—WATER NEEDS AND PROBLEMS

U. S. ARMY ENGINEER DISTRICT, ST LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

JANUARY 1964

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THE MERAMEC BASIN

Report of the Meramec Basin Research Project

to the

Meramec Basin Corporation

Kirkwood, Missouri

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by

Edward L. Ullman, Ronald R. Boyce, [redacted] Donald J. Volk

[redacted]

Blair T. Bower

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Meramec River, Missouri Comprehensive Basin Study.

Volume III. of 3 Volumes

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ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE.

See also Volume 4, AD-A036 827.

Meramec Basin Research Project
Washington University
St. Louis, Missouri
December 1961


THE
MERAMEC BASIN REGION
GENERAL MAP
ST. CHARLES
ST. LOUIS
FRANKLIN
GASCONADE
MARIES
PHELPS
CRAWFORD
WASHINGTON
JEFFERSON
DENT
IRON
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THE MERAMEC BASIN

Volume III

Water Needs and Problems

Chapter 1

METHOD OF ECONOMIC ANALYSIS

[illegible] Basin Research Project
Washington University
St. Louis, Missouri
[illegible]

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Chapter 1

METHOD OF ECONOMIC ANALYSIS

Varying viewpoints exist concerning the utility of benefit-cost analysis for water resources investment decisions.[1] Even among those who agree that such analysis is useful, there are many controversies over the details of the analysis -- the rate of interest, the length of planning period, the price level, and so on. This chapter does not enter into controversial issues and discussions, but it contains simply an enumeration and a discussion, where necessary, of the assumptions used in the economic evaluation and analyses of alternative water resources systems in the Meramec Basin. The position adopted in the investigations of the Meramec Basin Research Project is that benefit-cost analysis is useful in assessing the economic worth of water resources systems. To adopt this position is not to maintain that economic criteria are the only ones by which such investment decisions should be made.

Economic analysis of water resources systems can be made on one or more of three levels. The first is the local level, i.e., the immediate area of a proposed reservoir. The second is the regional level. A region may be an entire river basin or some areal unit larger than the river basin. The third is the national level which encompasses the entire national economy. Benefits associated with water resources systems on one level may not be considered benefits on another level. For example, from the standpoint of a regional economy the benefits which are generally termed "secondary" or "stemming from" may well be significant. However, from the standpoint of the national economy, such benefits are likely to be negligible or insignificant, because they merely represent economic resources diverted from one area of the national economy to another area. To put it another way, if such resources had not been allocated to processing products stemming from water resources systems in the particular region under investigation, they would have been devoted to other productive enterprises elsewhere in the country, assuming a full employment economy.

Economic Assumptions and Procedures Used in Benefit-Cost Analyses

For the economic evaluation of proposed alternative water resources systems in the Meramec Basin, the assumptions, criteria, and procedures described in the following pages were adopted. Differences of opinion may exist with respect to the desirability and/or validity of some of the assumptions. Setting forth the assumptions specifically makes possible their appraisal.

1. All benefits were evaluated from a national level. Because portions of the Meramec Basin have been designated as "depressed areas", one might argue that the viewpoint to be adopted in the economic analysis should be that of the regional level. However, adopting the regional level as the basis for economic evaluation implicitly assumes that redistribution of income to the particular region is an objective. A decision to make areal redistribution of income an objective of water resources development should be made only after an evaluation of national purposes and goals. Such an evaluation was not attempted by this project.[2]

2. Because of sizable uncertainties involved in the prediction of future economic and technological conditions, and because of the low value placed upon benefits which accrue in the distant future due to the discounting procedure used, use of a period greater than 50 years was not considered advisable -- even though the physical life of some of the facilities may be longer than 50 years. In fact, because of the uncertainties involved -- especially economic -- one might argue that a planning period shorter than 50 years might well be desirable in considering investment in water resources development.

3. The choice of a beginning point for the 50-year planning period can materially influence the calculated benefits. Ideally, it should coincide with the construction of the structures needed to derive the postulated benefits. Use of the year 1961 is not wholly realistic, since no construction will be underway, and none of the benefits will accrue at that time. However, the use of a later beginning point extends the period of analysis further into an already dim and

distant future. Therefore, the year 1961 was generally used as the beginning of the planning period. However, in computations in which the beginning point was critical to the benefit estimation, benefits were calculated using several different time periods and the results of each set forth to show the range of benefits possible under different assumptions.

4. The economic criterion by which alternative water resources systems were compared was net benefits, i.e., benefits minus costs. Benefit-cost ratios were calculated also.

5. In applying the net benefits criterion, total system benefits were compared with total system costs. Benefits related to each unit in the system were not computed. Because it is the total water resources system which provides the benefits, any allocation of benefits to individual units in the system is to some extent arbitrary.

6. Because a dollars worth of benefits at some time in the future is not valued by society as highly as a dollars worth of benefits at the present time, the time stream of benefits was discounted to obtain the present value of the benefits. Similarly, the time stream of operation, maintenance, and replacement (OM&R) costs was discounted to obtain the present value of these costs. The present value of the OM&R costs was subtracted from the present value of the benefits. The difference was then compared with the total first capital costs.

This procedure should not be construed as implying that the accuracy and precision of the benefit estimates are such that benefits in each year in a future 50-year period can be identified and accurately estimated. However, using a time stream of benefits and a corresponding time stream of costs is a consistent procedure in terms of economic analysis, and, in fact, does represent the actual manner in which benefits will be obtained and costs will be incurred over time. The use of multiple time streams of benefits and costs stemming from multiple sequences of hydrology mitigates, at least somewhat, any odious implications of precise values of benefits for any one year.

7. Interest rates of 2.5% and 4% were used to discount future benefits and costs throughout the period of analysis. As with the level of employment, the difficulty of predicting variations in the interest rate over a 50-year period seems insurmountable. The former rate is the long-term risk-free rate which has been used by the federal agencies for some time. The latter rate is one which has been suggested by at least one knowledgeable economist in the water resources field.[3] This rate is perhaps closer to a true measure of both the social time preference of society and of the alternative opportunity costs foregone, than are interest rates either higher or lower. As mentioned above, the "proper" interest rate to use in discounting future benefits and costs is one of the major controversies in the water resources field. One point which should be noted here is that the low rate of interest, 2.5%, has the effect of redistributing income from the national economy to the particular regional area in which the water resources development is undertaken.[4]

8. A full employment economy was assumed to exist throughout the time period of analysis. Therefore market prices (or imputed market prices) can be presumed to reflect accurately the cost of the resources involved in the water resources systems under investigation. The alternative is to attempt to predict the basically unpredictable variations in employment level over time, i.e., the 50-year planning period.

9. The price level was assumed to remain constant throughout the 50-year period of analysis. As for employment levels and interest rates, predicting variations in price levels over time seems virtually impossible. All benefits and costs were determined in December 1959 dollars.

10. Ideally, incremental analysis should be applied in the analysis of alternative water resources systems.[5] Each increment of a proposed water resources system should be analyzed separately to insure that the costs of adding the increment are less than or equal to the benefits to be gained from that increment. However, time and data limitations permitted only rudimentary incremental analysis to be applied to various water resources systems proposed for the Meramec Basin.

This analysis indicated decreasing returns for providing "complete" protection. The recommendations of the Meramec Basin Research Project therefore cover only the first phase of development. Additional measures contemplated in the future should be re-evaluated in light of experience gained in the first phase.

11. Cost allocation, where applied, was done by the separable costs remaining benefits method and was applied only to the total system. No attempt was made to allocate costs among units within the system. Such allocation inevitably must be arbitrary to some extent, because the benefits from a water resources system are produced by the total system.[6]

Outputs and Benefits from Water Resources Systems

Water resources systems can produce various outputs, as is illustrated in Figure 1. The specific outputs, such as flood damage reduction and power, relevant to water resources systems in the Meramec Basin, and the monetary benefits associated therewith, are noted and/or discussed in the following pages. In the discussion the phrase, "alternative water resources systems", refers to proposed systems. No such system is presently in existence in the Meramec Basin.

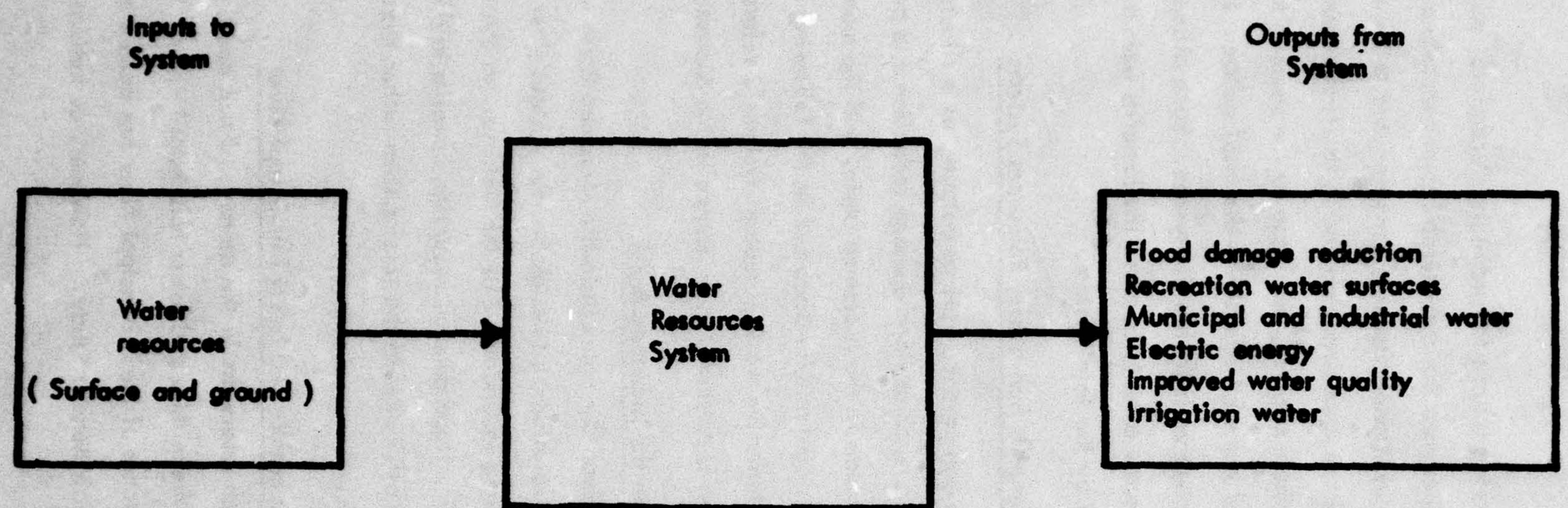
Flood damage reduction within the Meramec Basin

Benefits from reducing flood damage within the Meramec Basin were analyzed using flood damage-discharge relationships developed for various river reaches in the basin. Details are contained in Chapter 2 of this volume. In the analysis of any one water resources system, flood damage reduction benefits in damage areas common to all reservoirs were attributed to the total system rather than to individual reservoirs in the system.

Flood damage reduction in the middle and lower Mississippi River

One of the outputs which reservoirs in the Meramec Basin could produce is flood damage reduction on the middle and lower Mississippi River. Flood damage reduction in these reaches of the Mississippi River has been analyzed in the Mississippi River Reservoir Benefit Study.[7] However, as indicated in an

A WATER RESOURCES SYSTEM



Water resources have quantity, quality, time and place characteristics.

The desired outputs -- in general -- have quantity, quality, time and place characteristics.

A water resources system is a configuration of structural facilities and nonstructural measures ---- reservoirs, levees, pipelines, treatment plants, flood warning systems, drainage facilities, flood plain zoning regulations, wells, etc. -- and a procedure for operation. The system transforms the water resources into the outputs of water and water-related products and services.

appendix, flood damage reduction benefits on the Mississippi River attributable to Meramec Basin reservoirs have been overestimated. In addition, because floods on the Mississippi River are generally of long duration, it would be necessary to hold water in Meramec Basin reservoirs for long periods of time. Such long holdout periods might have negative effects on some outputs within the Meramec Basin, such as recreation. Since recreation is of major importance in the Meramec Basin, operation studies of proposed alternative water resources systems in the basin did not include specific operation to reduce flood damage on the middle and lower Mississippi River.

Even without operating Meramec Basin reservoirs specifically for flood damage reduction on the Mississippi River, some incidental benefits from this source would accrue to the reservoirs in the course of operating the reservoirs to reduce flood damage within the Meramec Basin itself. In evaluating alternative water resources systems, it was assumed that any reduction in outflow from the Meramec River down to 22,000 cfs at the gaging station, Meramec River near Eureka, would be credited with flood damage reduction benefits on the Mississippi River, if a Mississippi River flood occurred during the same time period. A unit value of $1.00 per cfs reduced was assumed to be the benefit, based on analyses in the previously mentioned Mississippi River Reservoir Benefit Study. This unit value was assumed to be the same regardless of the magnitude of the Mississippi River flood and the time of year.

Also as indicated in the appendix on Mississippi River floods, Meramec River floods do not always coincide with Mississippi River floods. Based on the historical record, a Mississippi River flood coincides with a Meramec River flood one out of two times on the average. To determine which of the floods in the Meramec Basin coincide with a Mississippi River flood, a set of random numbers was used. For each flood month in the Meramec Basin, a random number was drawn which indicated whether or not a Mississippi River flood occurred simultaneously. If flows at Eureka were reduced when floods coincided, benefits were attributed to Meramec Basin reservoirs for reducing floods on the Mississippi River.

Navigation

Another output which could be produced by reservoirs in the Meramec Basin is improvement of navigation conditions in the middle and lower Mississippi River. Releases from Meramec Basin reservoirs during periods of low flow on the Mississippi River could improve navigation conditions, particularly in the reach between the mouth of the Meramec River and Cairo. However, as indicated in the navigation appendix, low flow benefits on the middle and lower Mississippi River have been overestimated.

In addition there are possible intrabasin disbenefits stemming from utilization of reservoirs in the Meramec Basin for navigation on the Mississippi River. Regardless of whether releases for navigation on the Mississippi River are begun in late summer, early fall, late fall, or early winter, if the total amount of water released is several hundred thousand acre feet, the reservoirs in the Meramec Basin are not likely to refill to the normal recreation pool level by June 1 when the primary recreation season in the Meramec Basin begins. Even with smaller releases for navigation, there will be times when the reservoir level does not regain the recreation pool by the beginning of the recreation season. In the hypothetical operating studies made by the Corps of Engineers,[8] there were 4 years out of 18 in which the reservoirs did not regain the desired recreation level by June 1.

In addition, if a change should occur in the manner of operating the main stem reservoirs on the Missouri River, i.e., more water were released than at present during the winter season in order to produce power,[9] less water would be needed from tributary reservoirs to firm up low flows on the Mississippi River during the winter season. In any case, operation of tributary reservoirs, such as those proposed in the Meramec Basin, to produce benefits on the Mississippi River should be considered in relation to potential disbenefits -- such as to recreation -- within the tributary basins.

For these reasons, operation studies of proposed reservoirs in the Meramec Basin did not include operation in the interest of navigation on the Mississippi River.

No credit was taken for whatever incidental benefits to navigation might be obtained by releases from Meramec Basin reservoirs.

With respect to navigation within the Meramec Basin itself, there appears to be no need either for canalization of the lower Meramec River and/or for making releases to augment low flows in the Meramec River for navigation. As indicated in the appendix on the St. Louis industrial land situation, there is adequate land in the St. Louis Metropolitan Area for all foreseeable industrial needs. Niland[10] notes that there is no lack of river sites in the St. Louis Metropolitan Area and that the growth rate for the water-oriented industries in the area is relatively slow. Therefore, neither canalization of the lower Meramec River, nor operation of proposed Meramec reservoirs to provide navigation on the Meramec River were considered.

Water supply benefits

It is estimated that only in the lower Meramec Basin will there be any future need for additional water to meet municipal and industrial requirements. Water supply benefits which could be met by releases from reservoirs in the Meramec Basin will accrue only from meeting the water requirements in that area. The detailed analysis of water supply benefits attributable to the reservoirs is contained in Chapter 3.

Fisheries

Improvement in fish habitat within the Meramec Basin would probably be accomplished by releases from reservoirs. No benefits were credited to water resources systems because of this output. It is difficult to determine dollar benefits associated with the improvement in fish habitat. Since fishing in the Meramec Basin is primarily a recreational activity, benefits from improvement in fish habitat were assumed to be included in recreation benefits.

Recreation

There is little doubt that there is a demand for water-based recreation facilities in the area within and adjacent to the Meramec Basin, particularly in

the growing St. Louis Metropolitan Area, as indicated by studies of reservoir recreation by both the Meramec Basin Research Project and the Outdoor Recreation Resources Review Commission.[11] The difficulty lies not in determining that there is a demand for water-based recreation facilities in the St. Louis Metropolitan Area, but in evaluating the benefits from providing such recreation opportunities.

In estimating benefits from providing recreation opportunities at reservoirs in the Meramec Basin, a somewhat arbitrary figure of $.60 per visitor-day was used. The figure does have some basis in reality, however, since it approximates the consumer's surplus derived from providing a nearer reservoir (in terms of travel and time savings). [See Chapter 5.]

Population in the area to be served by a Meramec reservoir is expected to double by the year 2000. Because of simultaneous increases in income, leisure, and mobility, the predicted use in the year 2000 is four times as great as the predicted use for the year 1960. A development period of ten years after the construction of reservoirs was assumed before recreation use reached the predicted levels.

In order to obtain the number of visitor-days and the magnitude of benefits estimated, it must be assumed that adequate recreation facilities will be provided, (however, the calculations of consumer surplus are based on limited public recreation facilities). These would include a wide variety of facilities -- boat docks, boat launching areas, campgrounds, picnic areas, swimming beaches, and so on. Recreation facilities would presumably be provided by both the public and the private sectors of the economy.

The assumed development period reflects the fact that there is often a lag in private expenditures for various facilities such as motels, concessions of various types, and restaurants, after recreation water surfaces become available through public investment. It should not be assumed that the required private capital will immediately flow into an area following the public investment. Generally, alternative investment opportunities will exist for private capital. The development period in the Meramec Basin might well be longer than ten years, in terms of the

time required for facilities to be developed which would meet the demand represented by the level of visitor-days posited.

The costs of recreation facilities at various reservoirs were obtained from cost estimates contained in the previous Corps of Engineers' study, and from other sources. A considerable sum was set aside for purchase of land around the reservoirs, as well as for the capital costs of recreation facilities. The capital costs were included as part of the initial investment. Annual OM&R costs were assumed to increase in the same manner as the increase in recreational use.

It should be noted that the problem of estimating recreation benefits in monetary terms has not been solved by the Meramec Basin Research Project. It should also be noted that there is a question of spillover effects.[12] That is, it appears impossible to separate the recreation benefits stemming from public investment and those stemming from private investment at a single reservoir. It is the total package of facilities which attracts the total mass of visitors and results in the benefits.

Power

The potential for production of hydropower in the Meramec Basin is relatively small. The FPC[13] has estimated a total potential of 30,000 kw at three sites in the basin. The head and the amount of water available are insufficient to produce significant amounts of firm power. Production of the maximum amount of firm power possible would require relatively large reservoir drawdowns, thereby decreasing the desirability of the reservoirs for recreation. If large quantities of peaking power were to be produced at reservoirs in the basin, large variations in flow rates downstream from the reservoirs would result. To preclude large fluctuations in flow rates with peaking operations, reregulating structures would be necessary. With the relatively small amount of peaking power available even on the basis of a 10%-15% load factor, it does not seem likely that the value of the peaking power could cover the additional costs of reregulating structures. Because production of either firm or peaking power in a conventional hydroplant did not appear to be economically justified -- considering disbenefits to other purposes, primarily

recreation -- no investigation was made of potential power production at upstream reservoir sites in the Meramec Basin.

However, in the investigation of a major reservoir on the lower Meramec River just downstream from the confluence of the Big and Meramec rivers, it was suggested[14] that it would be economically feasible to produce a small amount of power if it were assumed that a constant flow of 1,000 cfs were desired downstream from the reservoir. Since the conduits which would be installed through the dam to make releases for other purposes, i.e., maintenance of a constant flow of 1,000 cfs downstream from the reservoir, would already be in existence, the additional investment for the power facilities would be relatively small in relation to the potential return. Other than for this alternative, no power production was proposed in any of the alternative water resources systems investigated.

Another possible method of power production which has received increasing attention in recent years is that of pumped-storage.[15] Generally for economical pumped-storage power development, either a high head or a large amount of water is desirable. Neither of these conditions seems to be met in the Meramec Basin. However, no detailed investigation of pumped-storage possibilities was made. It is possible that if pumped-storage power developments were analyzed on an incremental basis, i.e., charging no reservoir costs against the power facilities, that such power development might be economically feasible. In favorable circumstances it might even contribute something to reservoir construction costs and thus make the whole project more feasible.

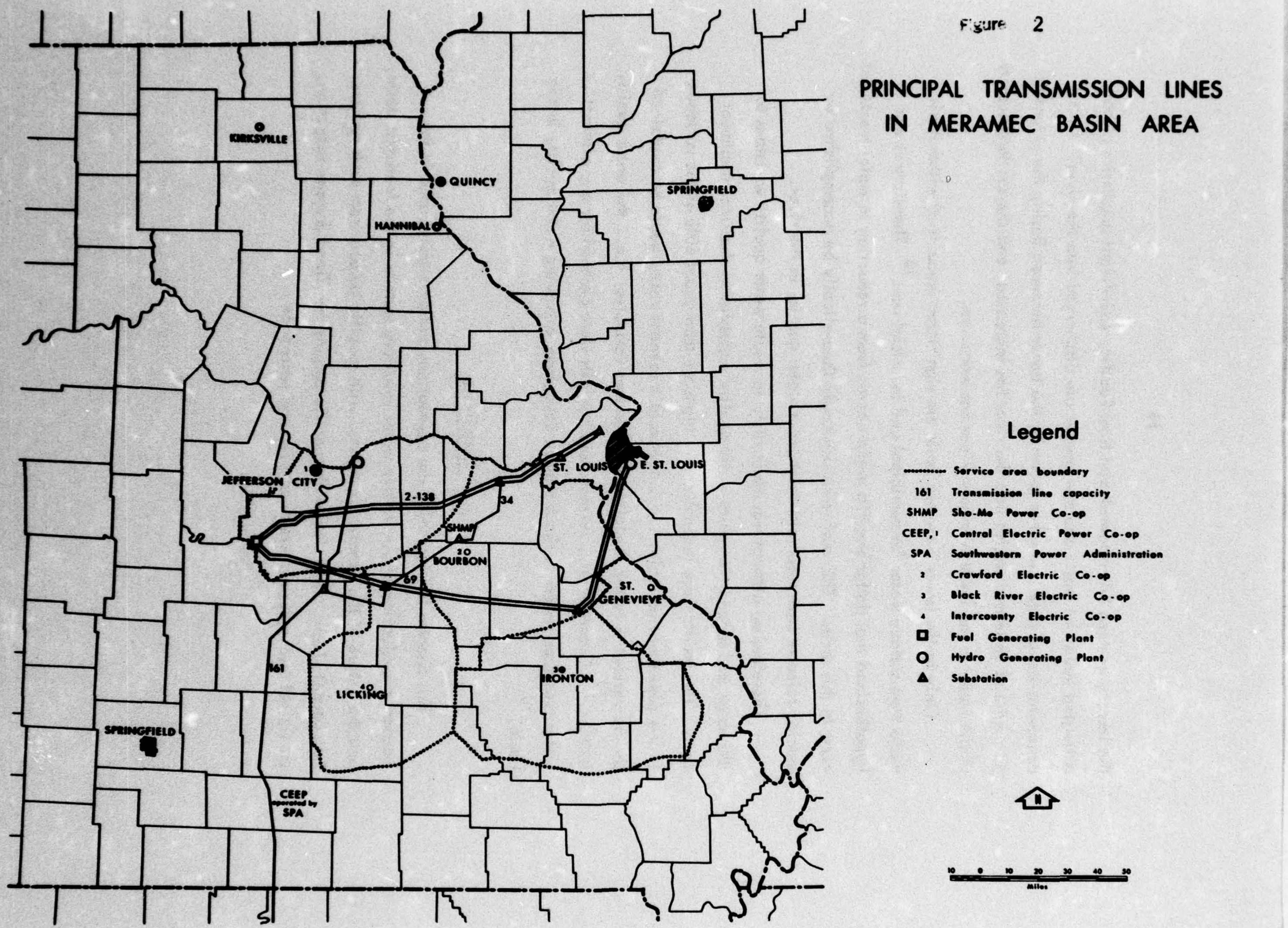
There appears to be little question that any power which could be economically produced at reservoirs in the Meramec Basin could be marketed. The Meramec Basin is located close to the major load center in the region -- St. Louis Metropolitan Area -- and is crossed by or is adjacent to existing major transmission lines. (See Figure 2.)

Water quality improvement

Because of the relative sparseness of population and industry in the Meramec Basin, water quality is a significant problem in only one section of the basin. In

Figure 2

PRINCIPAL TRANSMISSION LINES IN MERAMEC BASIN AREA



the lower Meramec River downstream from Pacific, significant quantities of both untreated industrial waste and raw sewage are discharged into the river. As the concentration of population has grown in the lower Meramec Basin, the extent of discharge of untreated wastes into the river has increased, and the sanitary quality of the water in the lower Meramec River has worsened.

Only in the lower Meramec Basin are significant amounts of withdrawals made from surface water for municipal and industrial use.[16] Therefore it was hypothesized that dollar benefits might accrue from a reduction in water treatment costs in this area. This cost reduction could theoretically be accomplished by making releases from reservoirs to improve water quality in the river.

Therefore an attempt was made first, to relate water quality variables to discharge, and second, to relate water quality variables to chemical treatment costs. The results were inconclusive. No more than about 40% of the variance in the dependent variable, i.e., chemical treatment costs, could be explained by the variations in the so-called independent variables, i.e., the water quality indices.[17] Consequently, no monetary benefits were claimed for any alternative water resources system in the Meramec Basin from improving water quality in the basin.[18]

Conclusion

This chapter has indicated the assumptions and procedures used in the economic evaluation of alternative water resources systems in the Meramec Basin, and the nature of the benefits associated with specific outputs from such systems. Subsequent chapters will deal with specific outputs -- flood damage reduction, municipal and industrial water supply, and recreation.

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2. See the discussion in Marion E. Marts, "Regional vs. Local Level: Objectives and Social Accounting of the Columbia Basin Project." Papers and Proceedings, Regional Science Association, 1961, forthcoming. A desirable approach is to present economic evaluations from both the national and regional levels.

3. R. Dorfman, Water and Welfare, Paper presented at the Annual Meeting of the American Economic Association, St. Louis, 1960.

4. John V. Krutilla, "Water Resources Development: The Regional Incidence of Costs and Gains," Papers and Proceedings, Regional Science Association, Vol.4, 1958, pp.273-300. See also Marts, op. cit.

5. Marion Clawson and Irving K. Fox, Your Investments in Land and Water, Reprint No. 27, Resources for the Future, Washington, p. 17

6. On this point, see the discussion in the appendix on Mississippi River Low Flows. Also see the discussion in R. J. Hammond, Benefit-Cost Analysis and Water-Pollution Control, Food Research Institute, Miscellaneous Publication 13, Stanford University, Stanford, 1960, pp.62-63. Eckstein, op.cit (p.262), notes: "It is important to stress that cost allocation and benefit-cost analysis have very little in common. Allocation is an essential part of the financial analysis of projects, while benefit-cost analysis is the main component of the economic analysis. Since, by their very nature, cost allocations must be arbitrary, the introduction of their results into the benefit-cost analysis only serves to obscure the essentials of the economics of a project." (Emphasis added.)

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10. Powell Niland, The Role of River Sites in the Industrial Development of the St. Louis Region, Graduate School of Business Administration, Washington University, St. Louis, 1961, p. 22.

11. Outdoor Recreation Resources Review Commission, Progress Report, Washington, 1961, pp. 53-56.

12. See the discussion of spillover effects in McKean, op.cit., Chapter 8.

13. Federal Power Commission, Hydroelectric Power Resources of the United States, Developed and Undeveloped, FPC-26, Washington, 1953.

14. Sverdrup and Parcel Associates, Preliminary Study of a Proposed Earth Fill Multi-Purpose Dam on the Meramec River, St. Louis and Jefferson Counties, Missouri, St. Louis, 1961.

15. See Southwestern Power Administration, Pumped Storage: The New Frontier of Hydroelectric Development, The Administration, Tulsa, no date, and Corps of Engineers, Water Resources Policies and Authorities, Pumped Storage Hydroelectric Plants, Corps of Engineers, U. S. Army, EM 1165-2-110, March, 1961.

16. The city of Union is the only major population concentration outside of the lower basin where withdrawals from surface water are made for municipal and industrial purposes. However, present withdrawals at Union average less than 1 mgd.

17. The results of the regression analyses are available in a compilation of supplementary data on water quality investigations by the Meramec Basin Research Project.

18. Multiple regression analysis does not appear to be basically applicable to this type of problem, since the independent variables are not really independent. Multivariate analysis might have disclosed a significant relationship. Multivariate analysis has been used in investigations of the relationship between surface runoff and watershed variables. This is a problem which is similar to that with respect to water quality, that is, the independent variables are not independent in the sense required by the assumptions of correlation analysis. See B. Harris and others, An Improved Statistical Model for Evaluating Parameters Affecting Water Yields of River Basins and W. M. Snyder, Some Possibilities for Multivariate Analysis in Hydrologic Studies. Both papers were prepared for presentation at the Annual Meeting of the American Geophysical Union, Washington, April, 1961.

THE MERAMEC BASIN

Volume III

Water Needs and Problems

Chapter 2

FLOOD DAMAGE REDUCTION

Meramec Basin Research Project
Washington University
St. Louis, Missouri
December 1961

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Chapter 2

FLOOD DAMAGE REDUCTION

Summary

Flood damage is the result of human use of flood plains for various activities -- residential, commercial, industrial, recreational. These damages can be reduced by any of a number of methods, or some combination of them. Reducing flood damage involves more than controlling flood waters.

Floods in the Meramec are not a major problem, when compared to many other parts of the United States. The flood plains in most of the Meramec Basin are not highly developed at the present time. Only in the lower reaches, the area near St. Louis, is the flood plain intensively utilized. The benefits which might accrue from flood protection in the Meramec is partly dependent upon the demand for flood-plain land. Because of the requirement of industry for level land, the amount of this land available in the St. Louis area is thought by some to be critical. However, an analysis of the demand for and supply of industrial land made by the Meramec Basin Research Project resulted in the conclusion that there is adequate available land for industrial use in the St. Louis Metropolitan Area to meet all demands for such land in the foreseeable future. However, if the Meramec flood plain were protected, part of it would probably be used for industry. Additional acreage would probably be developed for residential and commercial use.

Recommended measures to reduce flood damage in the Meramec include flood plain zoning, building regulations, and improvement of the flood warning system, in addition to reservoir protection. (A workable flood insurance program would also be useful, and land treatment measures would be of some value.)

Methods of Achieving Flood Damage Reduction

Introduction

The need for flood damage reduction in the Meramec Basin exists because, as elsewhere, man has established his activities in the natural stream channels which sooner or later will be required to carry streamflows. Floods have occurred since time immemorial. Human activities may change stream channels somewhat or modify soil-vegetation relationships on watersheds, but man is not the cause of floods.

Flood damage, however, is a result of man's activities.[1] The flood plain of a river is a normal part of its channel (used only during times of high water, but certain to be used eventually). Thus, whenever a river overflows its banks and inundates a flood plain which man has occupied for residential, business, industrial, recreational, or other uses, flood damage results. The problem of reducing flood damages can be accomplished by various measures or combinations of measures. The more important of these measures are listed below. Not all of these are applicable to the Meramec Basin.

Relocation

An obvious means for eliminating flood damage is to relocate facilities which are in a flood plain to areas outside of the flood plain. This is not likely to be economically feasible in many cases. But it does have potential utility in some areas, such as where summer camps and resorts, for example, have been located in the flood plain and are subject to frequent inundation.

Flood plain zoning

Flood plains or portions thereof which are subject to frequent inundation can be zoned to prevent utilization which will result in large damages when floods occur.[2] This does not mean of course that all use will be eliminated from the flood plain. Rather, zoning provides for the establishment of uses which will be compatible with the potential flood hazard and will minimize flood damages. Some examples are grazing land, parks, and some types of playgrounds.

Building regulations

Building regulations can be established which require that construction of buildings in the flood plain must meet certain standards which are adopted to minimize damage from flood waters. Particular kinds of construction materials and building designs may be banned, and/or certain protective devices such as flood gates, bulkheads, and the like may be required. Buildings may not be permitted to have basements. Along the Meramec, numerous club houses built on stilts (essentially houses without a first floor) provide an excellent example of this kind of structural adjustment to some floods.

A related measure is to elevate the land above the level of flood waters by land fill. Care must be taken in land fill to avoid excessive constriction of the stream channel.

Channel encroachment restrictions

Regulations can be enacted to preclude the building of structures which would encroach on the channel of the river and thereby restrict unduly the capacity of the channel to carry flood flows.

Flood warning systems

In recent years, techniques for forecasting flood flows have increased in accuracy and utility.[3] Wherever flood forecasting has been developed, flood warning systems can be established which will notify flood plain occupants when flooding is imminent. This will enable them to remove property above the flood level, remove goods outside of the flood plain, reschedule operations, move machinery and equipment, and the like. All these things will reduce the damages which would otherwise accrue from flooding.

Channel improvement

Straightening of a stream channel, elimination of debris, stabilizing banks, and similar measures are sometimes practical in order to increase the carrying capacity of a river channel and so reduce the height of flood flows.

Floodways

If areas are available, as along the middle Mississippi and the lower Sacramento rivers, floodways can be established to carry flows which are in excess of the capacity of the river channels. Such floodways often can be used part of the time for non-intensive uses such as grazing. Only rarely does an area have topography suited to the construction of such floodways.

Levees and floodwalls

Levees and floodwalls can be constructed in order to confine flood flows within certain limits. However there is often a limit to the height to which such structures can be built. Since the possibility always exists that a flood higher than any which has

occurred in recorded history may some day take place, levees and floodwalls may be overtopped. When overtopped, the result is likely to be very large flood damages, as occurred in the Kansas City area in the flood of 1951, since the construction of levees and floodwalls generally leads to more intensive development in the flood plains behind them.

Reservoirs

Reservoirs of various sizes can be constructed to withhold flood flows and so decrease the frequency and extent of flooding. Small reservoirs and large reservoirs have roles to play in reducing flood damages in a river basin.[4] The small headwater reservoirs, especially in conjunction with land treatment measures, gully treatment, and channel improvement, are effective in reducing flood damages in the local areas and river reaches immediately below these reservoirs. However, they are of little help in reducing flood damages in the lower portions of a basin many miles downstream, especially for medium and high flood flows. At the same time, large reservoirs farther downstream can contribute nothing to reducing flood damages in the headwater areas above these reservoirs. Generally there is little overlap between the two types of programs -- that is, each program is effective in its own area. Both can be integral parts of an efficient program of flood damage reduction in a river basin.

Land treatment

Land treatment measures such as reforestation, contour plowing, establishment of grass waterways, and similar measures can contribute to reduction of flood damages in localized areas.[5] What these techniques do is to increase the infiltration capacity of the watershed and so reduce the amount of surface runoff from any given storm. However, it should be remembered that even with the best "vegetative" cover there is a limited infiltration capacity, which is often exceeded in high intensity rain storms. Further, the soil mantle is a "reservoir" which, like a man-made reservoir, has a total finite capacity for the retention of water. A typical clay-loam soil three feet deep might hold between four and five inches of water. Once the capacity of the soil mantle is exceeded, there is no other place for the water to go but to run off as surface flow.

The land treatment measures are most effective in storms of low intensity and low total precipitation -- say less than two to three inches.

Flood insurance

While flood insurance is not a means for directly reducing flood damages as such, it is a means by which the losses from flood damage may be spread over time. It is similar, for example, to crop insurance against hail and wind. The major problem with insurance is devising a way of making the premiums proportional to the risk. Determining the flood risk involves hydrologic and topographic studies of the stream and floodplain, and usually results in flood frequency maps which graphically show the flood risk for different sections of the flood plain. (Similar maps should be provided for efficient flood plain zoning and the like.)

Flood Problems in the Meramec Basin

In analyzing a particular proposal for flood damage reduction (a proposal for some combination of the previously discussed measures) benefits attributable to the combination or system are the difference between flood damages which would occur in the absence of the system and the damages which would occur with the system in operation; plus the benefits, if any, from change in land use with the system in operation. Against these benefits must be arrayed the costs required to achieve the benefits -- capital, operating, and maintenance costs of reservoirs, levees, land treatment programs, and the rest. If the benefits are sufficiently more than the cost, the system is considered to be economically justified. The problem of flood damage reduction requires consideration of the need for flood-free land at specific locations and at various times in the future. Precise estimates of future land use and related flood damages is difficult; the demand for flood plain land is affected by (1) changes in the demand for and supply of land, both within the immediate flood plain and in other areas in the region, and (2) the various measures adopted to reduce flood damage.

Present land use patterns in the flood plain

The flood plain in the Meramec Basin is not highly developed at the present time. As indicated in Table 1, only in the lower portion of the basin, in St. Louis

Table 1

PRESENT LAND USE IN MERAMEC BASIN FLOOD PLAIN[a]

River Reach	Intensive Use[b]	Good Agriculture	Fair Agriculture	Poor Agriculture or Vacant	Total
Meramec River, mouth to Pacific[c]					
St. Louis County	1,767	- - -7,850[d]- - -		4,524	14,141
Jefferson County, eastside	491	985	151	1,215	2,842
Jefferson County, westside	88	1,030	270	1,336	2,724
Meramec River, mi.49.0 to mi.64.8	58	2,015	478	1,820	4,371
Meramec River, mi.64.8 to mi.107.5	137	3,009	1,213	4,620	8,979
Meramec River, mi.107.5 to mi.143.0	120	1,443	939	4,198	6,700
Bourbeuse River, mouth to mi. 32.2	88	1,865	871	2,832	5,656
Bourbeuse River, mi.32.2 to mi.90.4	13	3,672	1,319	4,753	9,757
Bourbeuse River, mi.90.4 to mi.131.0	11	3,386	841	3,576	7,814
Big River, mouth to mi.22.6	285	3,529	1,131	1,739	6,684
Big River, mi.22.6 to mi.61.2	81	3,682	673	2,797	7,233
Big River, mi.61.2 to mi.113.0	52	1,701	609	3,251	5,613
Totals		26,317[e]	8,495[e]		
	3,191	42,662[f]		36,661	82,514

a Compiled from aerial photographs except where noted.
b Industrial, commercial, residential, etc.
c Compiled from St. Louis County Planning Commission Land Use Maps and from St. Louis County Planning Commission, "Statistical Analysis of the Meramec River Flood Plain in St. Louis County, Missouri", Processed, January, 1960.
d Sum of good and fair classifications.
e Excluding St. Louis County.   f Including St. Louis County.

and northern Jefferson counties, are there any significant concentrations of intensive development. In the remainder of the basin, the flood plains are utilized primarily for agriculture. There are scattered residential and recreational uses, sand and gravel operations, and secondary and tertiary roads in the flood plains. However, except for the area within Metropolitan St. Louis, the principal population concentrations in the basin are located on ridges or uplands, generally far outside the flood plains. The major highways, such as U.S. 50 and U.S. 66 (Interstate 44) and the railroads are likewise located along the ridges, except in the lower portion of the basin, from about Pacific downstream to the mouth of the Meramec River. In this latter area, however, both the railroads and the major highways are elevated, so as to minimize damage even from a flood as large as the maximum flood of record. The general nature of present flood plain occupancy in most of the Meramec Basin is shown in the maps at the end of this chapter.

Present land values in the flood plain

Since flooding of land presumably has some effect on the value of the land, attempts were made to determine the present value of flood-plain lands and to see if there were measurable differences between the value of land in the flood plain and the value of land adjacent to, but outside of the flood plain. Two investigations were undertaken: (1) a determination of the average value per acre for different types of land use based on actual land and building sales in the St. Louis County portion of the Meramec River flood plain; and (2) an inventory, by means of aerial photographs, of the different types of land use found in selected reaches of the flood plains in the Meramec Basin. As detailed land use and land sales data were available for that portion of the flood plain in St. Louis County, this area was used as a guide for working out land use - land value relationships in other portions of the flood plain.

It was found that about 14,000 acres of land are in the Meramec flood plain in St. Louis County. The value of the land and structures (based on separate calculations for incorporated and unincorporated areas, roads, railroads, and

utilities -- as explained in Appendix A at the end of this chapter) was found to be approximately $23,800,000. A check was made using a more detailed land-use breakdown and average values for different land uses. The value of land and structures in the St. Louis County portion of the Meramec flood plain was calculated by this method to be $23,600,000. An additional check on the validity of the above estimate is provided by the St. Louis County Planning Commission,[6] who estimate the value of flood-plain land and structures to be about $20,000,000.

Based on the results of these analyses, adjustments were made to arrive at the land values alone (without structures), and estimates were compiled for other reaches of the major streams of the lower Meramec Basin. These are shown in Table 2.

Because of the paucity of the available data, it was impossible to make any significant comparison of the value of land subject to periodic flooding and the value of adjacent land not subject to flooding.

Future land use patterns in the flood plain

Since almost all of the existing urban and intensive land use in the Meramec Basin, except in the St. Louis Metropolitan Area, is located outside of the flood plain, little development is expected in the flood plains in the future. Expansion of existing population concentrations in the basin could take place virtually indefinitely without encroaching upon the flood plains. Only in that portion of the basin within the expanding metropolitan area is there a potential demand for significantly increased use of the Meramec River flood plain.

As the St. Louis Metropolitan Area grows, land uses typical of urbanized areas, residential and commercial primarily, spread into the surrounding countryside. Intensity of land use within the metropolitan area varies with distance from the city center. The farther away from the city the less intensive is the land use. This is illustrated in Figure 1.

The flood plain of the Meramec River lies athwart the spreading wave of urbanization in the St. Louis Metropolitan Area. (See frontispiece map.) Along the major radial highways in particular, residential and commercial development

Table 2

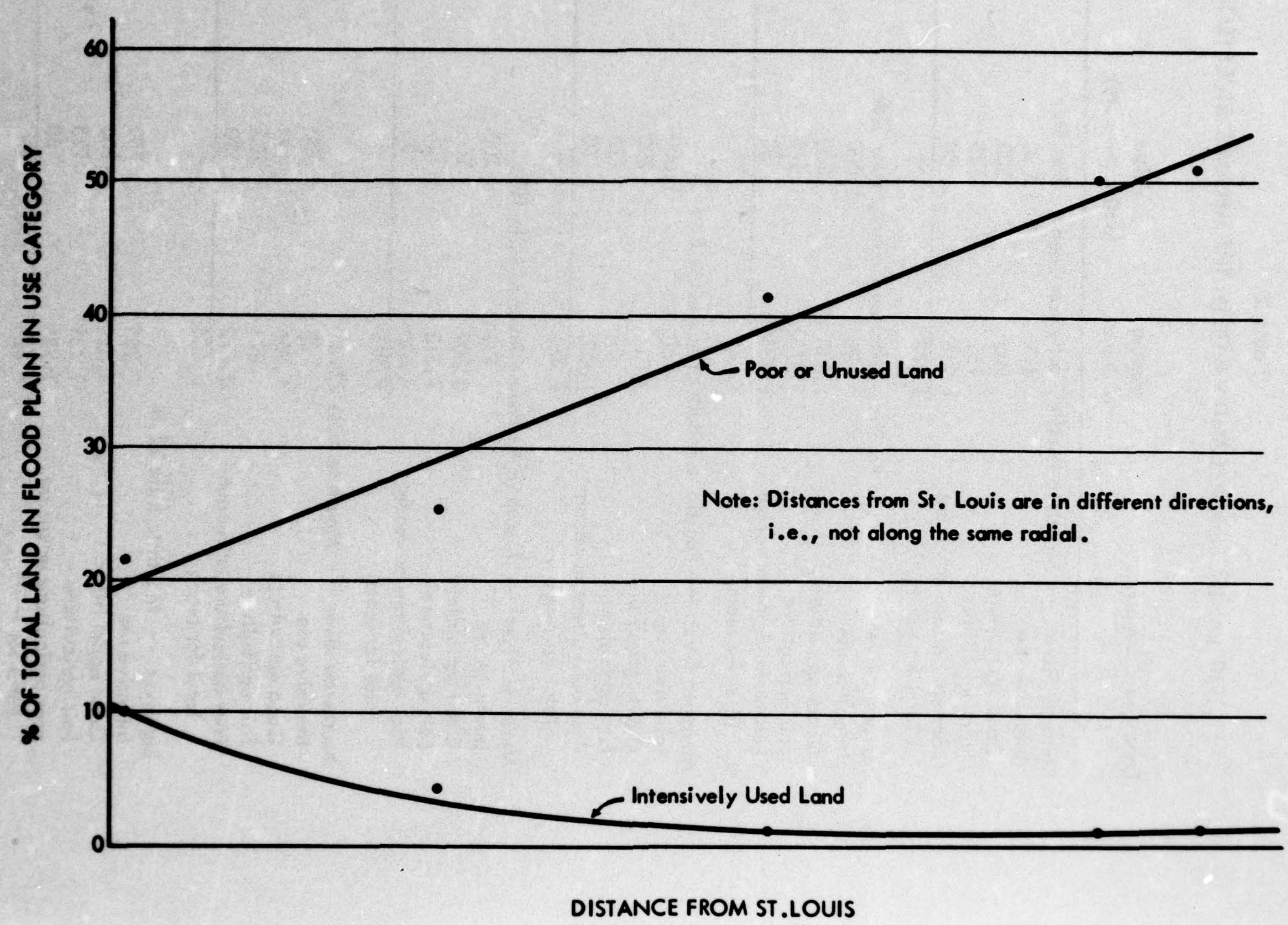
1960 LAND USE AND LAND VALUE IN THE MERAMEC RIVER FLOOD PLAIN

Land Use Category	Number of Acres	Value (dollar per acre)	Value (dollars)
Meramec River -- Mouth to Pacific, Jefferson County, East Side			
Intensive use	491	$ 1,500	$ 737,000
Good agriculture	985	200	197,000
Fair agriculture	151	125	19,000
Poor agriculture or vacant	1,215	50	61,000
Total for reach . . .	2,842	--	1,014,000
Meramec River -- Mouth to Pacific, Jefferson County, West Side			
Intensive use	88	1,000	88,000
Good agriculture	1,030	200	206,000
Fair agriculture	270	125	34,000
Poor agriculture or vacant	1,336	50	67,000
Total for reach . . .	2,724	--	395,000
Meramec River -- Pacific to Mouth of Bourbeuse River			
Intensive use	58	1,000	58,000
Good agriculture	2,015	200	403,000
Fair agriculture	478	125	60,000
Poor agriculture or vacant	1,820	50	91,000
Total for reach . . .	4,371	--	612,000
Meramec River -- Mouth of Bourbeuse River to Mile 107.5			
Intensive use	137	500	69,000
Good agriculture	3,009	200	602,000
Fair agriculture	1,213	125	152,000
Poor agriculture or vacant	4,620	50	231,000
Total for reach . . .	8,979	--	1,054,000
Bourbeuse River -- Mouth to Mile 32.2			
Intensive use	88	500	44,000
Good agriculture	1,865	200	373,000
Fair agriculture	871	125	109,000
Poor agriculture or vacant	2,832	50	142,000
Total for reach . . .	5,656	--	668,000
Big River -- Mouth to Mile 22.6			
Intensive use	285	750	214,000
Good agriculture	3,529	200	706,000
Fair agriculture	1,131	125	141,000
Poor agriculture or vacant	1,739	50	87,000
Total for reach . . .	6,684	--	1,148,000

NOTE: Land use data determined from aerial photographs.

Figure 1.

RELATION BETWEEN DISTANCE FROM ST. LOUIS AND USE OF FLOOD PLAIN



has occurred. Because of periodic flooding in the flood plain, the intensity of development is less than in immediately adjacent areas, as shown in Figures 2 and 3 which depict variations in residential density with distance from the city and the river.[7]

As the St. Louis Metropolitan Area grows, the demand for land for residential and commercial use in surrounding areas, including the Meramec River flood plain, can be expected to increase. However, new development in the flood plain itself is likely to be small, barring any measures to reduce the frequency and magnitude of flooding. Furthermore, there are many alternative sites outside the flood plain suitable for residential and commercial development. The alternative sites apparently have no locational disadvantages, other than distance from the city in the case of some sites, that would warrant protecting the flood plain of the Meramec River solely to provide land for residential and commercial development. However, the nearer portions of the Meramec flood plain undoubtedly would be put to more intensive use if flooding were abated. Nevertheless, the presence of relatively close sites elsewhere, means that Meramec land is not essential for proper urban development and might indeed serve general urban development policies better if left in a green belt for recreation and other purposes.

Future demand for industrial land

In assessing whether or not land in the flood plain of the lower Meramec River is needed for industrial expansion in the St. Louis Metropolitan Area in the future, an analysis is necessary of both the demand for and supply of land for industrial use. An analysis of the demand for industrial land and an intensive investigation of available industrial sites were made. The studies and the results are contained in full in an appendix.[8] In essence, the conclusion was that there is adequate available land for industrial use in the St. Louis Metropolitan Area to meet all demands for such land in the foreseeable future, certainly to 1980 -- and probably considerably beyond that date (see Figure 4).

Figure 2

RESIDENTIAL DENSITY CROSS SECTION OF MERAMEC RIVER AND VICINITY NEAR LEMAY FERRY ROAD

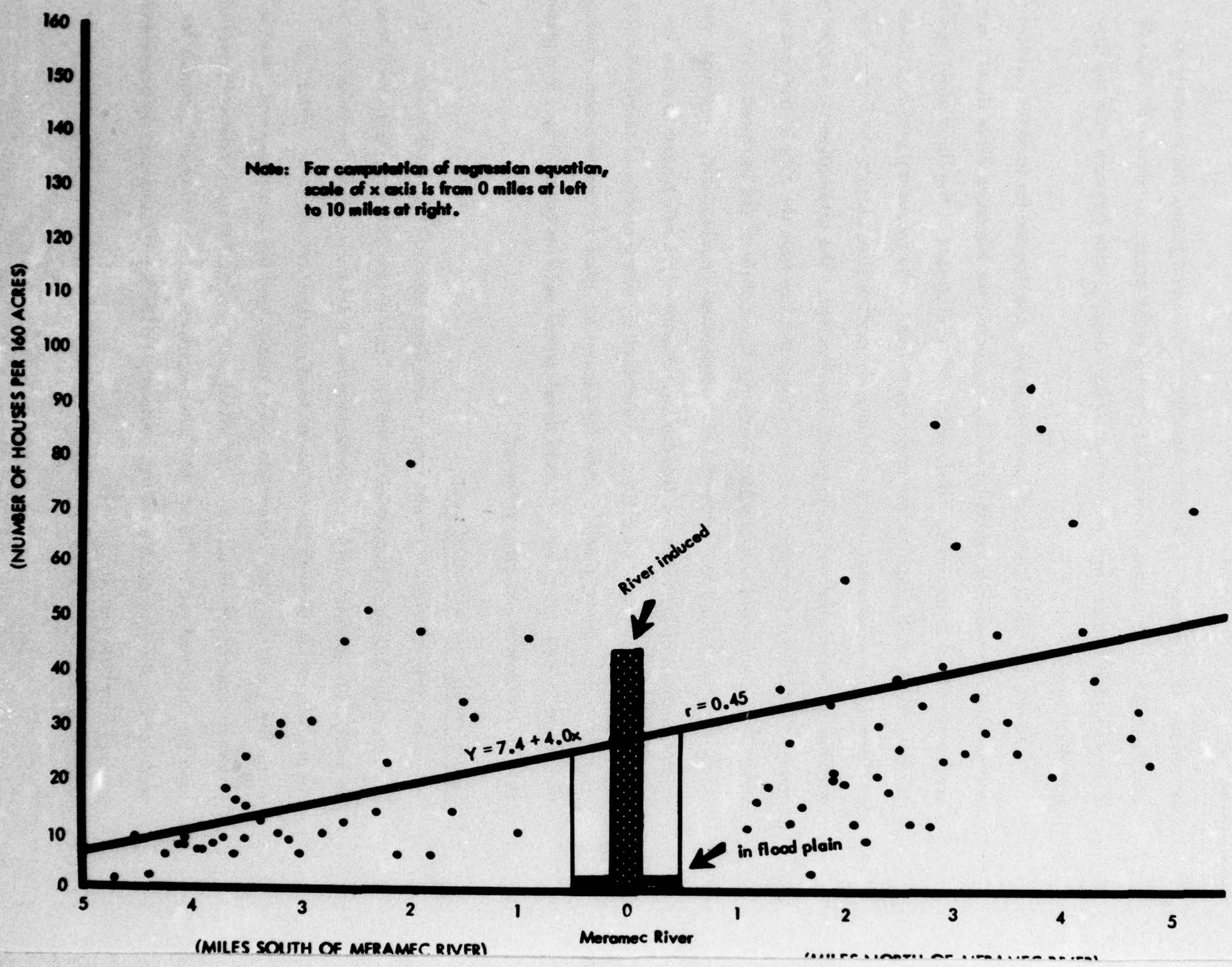


Figure 3

RESIDENTIAL DENSITY CROSS SECTION OF MERAMEC RIVER AND VICINITY NEAR HIGHWAY NO. 66

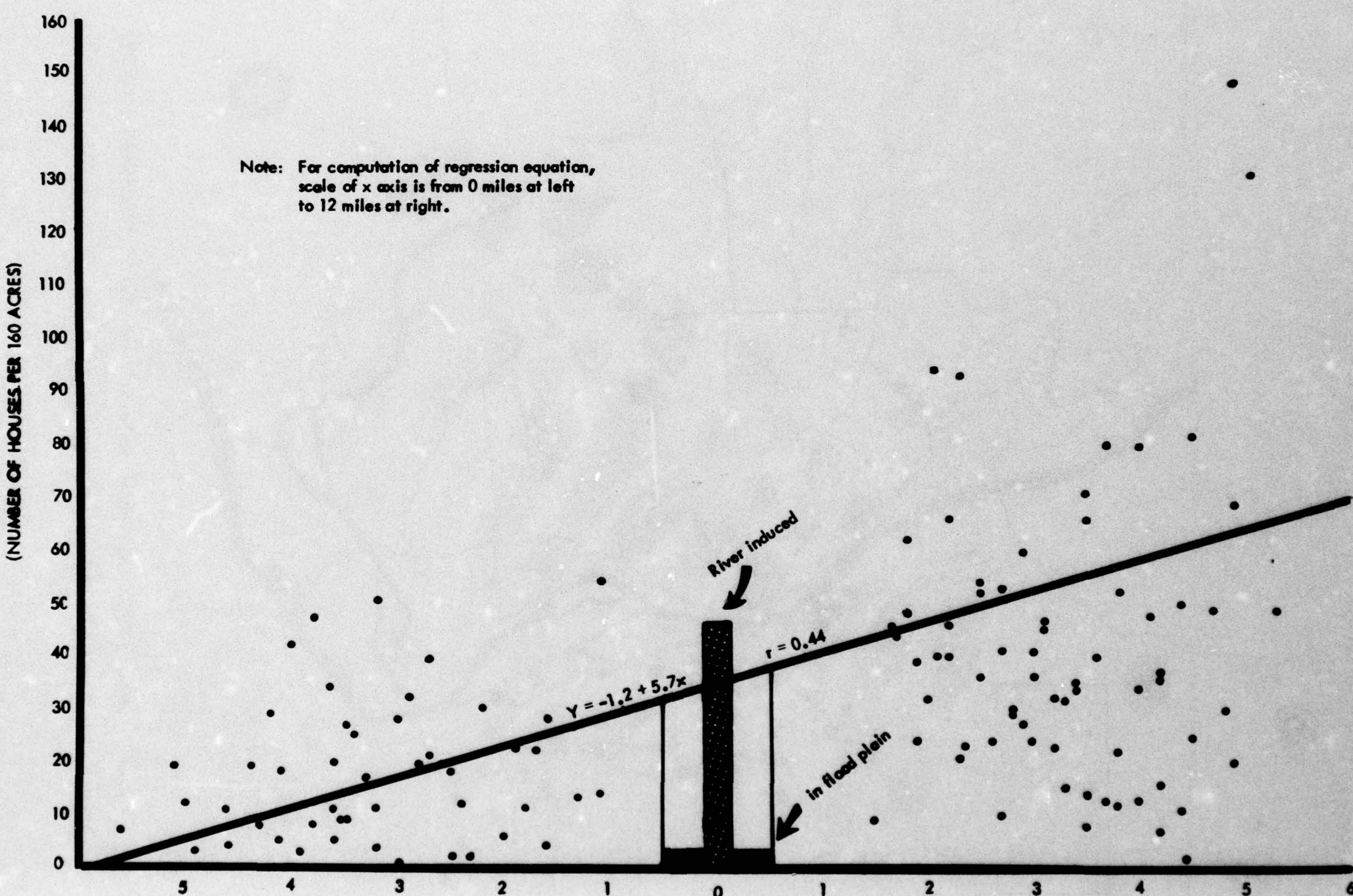
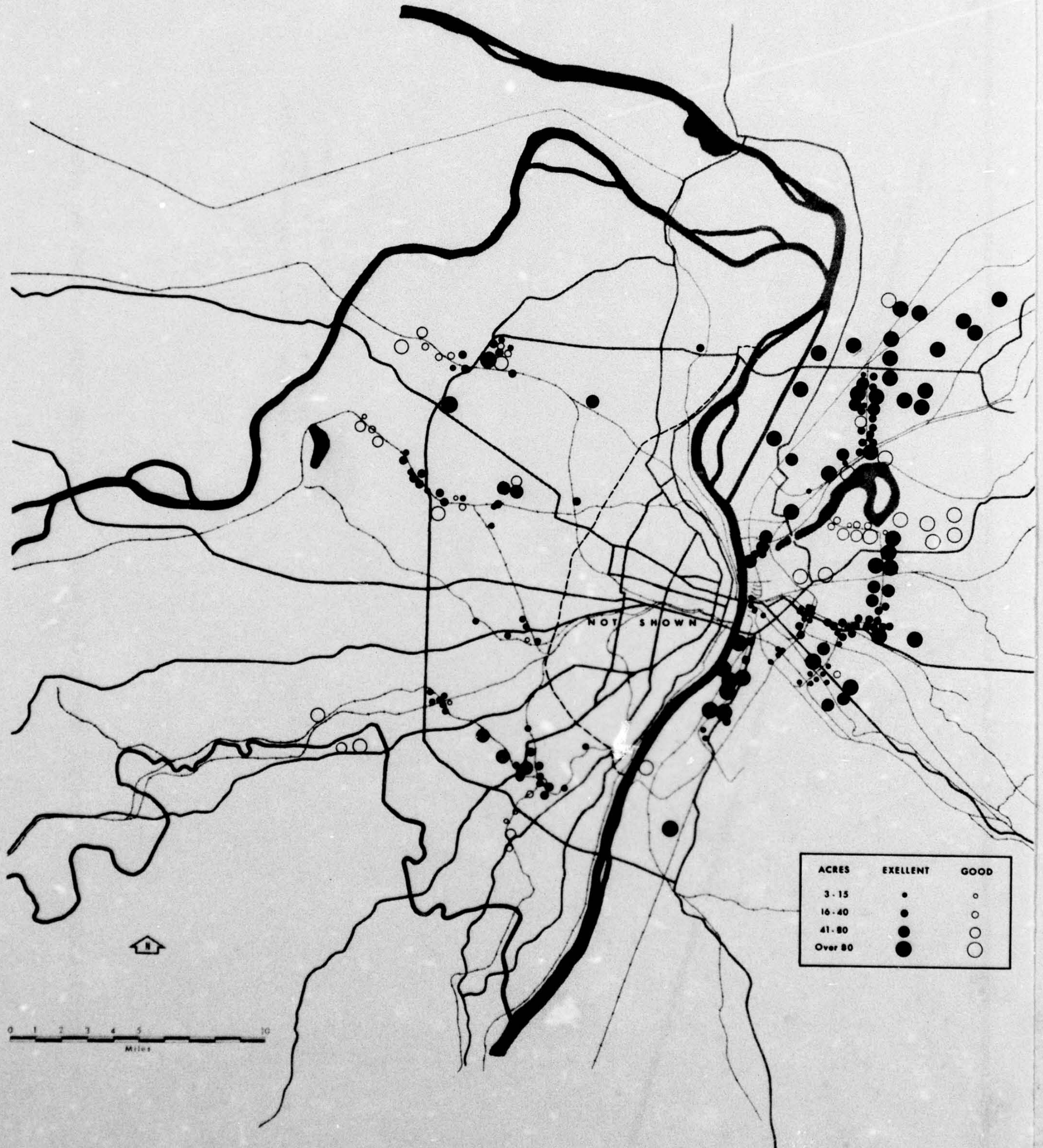


Figure 4

VACANT INDUSTRIAL SITES IN METROPOLITAN ST. LOUIS, 1960



This does not mean that there would be no benefits to industry in the event flooding were abated. Industry might, indeed, occupy some of the present flood plain in the event it were no longer flooded. It is therefore necessary to explore the probabilities of industrial development in the Meramec River flood plain in the event flooding were reduced or prevented.

Only the lower portion of the Meramec River, i.e., that portion in proximity to the built-up area of metropolitan St. Louis, has any likelihood for industrial occupancy. Even here the locations suitable for industry are very limited. The only areas where industry is located in, or close to, the Meramec River flood plain are at the north side of the confluence of the Meramec and Mississippi rivers, and in the vicinity of Valley Park. The Union Electric plant occupies a portion of the former area. This area is subject naturally to flooding from Mississippi River backwater, and therefore could not be made available for industry simply by reducing or eliminating Meramec River floods. The area in the flood plain near Valley Park which might be available for industry amounts to about 1,000 acres. However 500 acres of good industrial land located outside the immediate flood plain in this area are still unused.

Since periodic flooding precludes the extensive use of the above two areas in the Meramec River flood plain by industry, it might be expected that the Meramec River flood plain as a whole would not appear attractive to industry as far as general locational preferences are concerned. On the other hand, if the flood plain were a potential location for industry, it theoretically would have been reflected in the responses by industries to the question concerning preferrred or desired locations. Actually, the vicinity of Lambert Municipal Airport to the northwest of the center of St. Louis was the first choice of most industries desiring to relocate in the metropolitan area. The Meramec River sector was mentioned by only a few firms. Perhaps this is simply because it is little known; future location preferences might change especially if and when airport land is exhausted.

Based on data about factors affecting land use in the Meramec Basin, it was concluded that only in that portion of the flood plain of the Meramec River from

about mile 14 to about mile 40, would any significant increase in development be likely to occur in the future. Present land use in the flood plain of the lower Meramec River is shown in Maps 1 and 2 appended to the end of this chapter. The increased development in this reach was estimated to be primarily residential and commericial, with some industrial. The extent of increased development in this reach will of course depend on the degree to which the frequency and magnitude of flooding are reduced and on the land use plans adopted by St. Louis County.[9] But even without measures to reduce the flood hazard, some development is likely to take place in this area, because of the growing St. Louis Metropolitan Area.

Benefits from Flood Damage Reduction in the Meramec Basin

Nature of flood damage reduction benefits

Basically there are two types of benefits from reduction in the magnitude and frequency of flooding. The first includes benefits stemming from direct reduction in flood damages and associated costs. The second includes benefits stemming from increased intensity of land use, and hence an increase in land value, made possible by the reduction of the flood hazard.

The first type of benefit includes the reduction of both direct losses from flooding, i.e., damage stemming from direct physical contact with the water, and indirect losses, i.e., costs associated with flooding but not involving direct physical contact with water. Direct losses accrue to residences; commercial operations; industries; public facilities -- utilities, roads, parks, water and sewage systems, etc.; and agricultural property. Direct losses to agriculture include crop and livestock losses, damages to farm buildings, to farm equipment and to farm land itself, and replanting costs. Direct losses stem from the depth and duration of flooding, the velocity of the water, and the deposition of sediment carried by the water.

Indirect losses include the costs of flood fighting, evacuation, reoccupation; increased costs of business operations during and/or after the flood period; and loss

of stock to businesses and industries because of spoilage. Indirect losses also include the net economic loss of goods and services to the national economy resulting from flooding in the area. Since a national framework for the economic analysis of water resources systems in the Meramec Basin was adopted, the losses of goods and services must be net, i.e., actual losses not recouped later in either the area where flooding occurred or elsewhere in the nation. Given the degree of flexibility and substitutability in the national economy, little net loss of business or production is likely to occur nationally from flooding in a local area or in one region.[10]

The second type of benefit stems from the higher utilization of property and is measured by the increased net earnings of the land. Waste land may become usable for agriculture; agricultural land may be shifted from less intensive to more intensive farming; farm land may become usable for residential or industrial purposes. However, as noted previously, more intensive land use may occur in an area over time whether flooding is reduced or not. Historically-induced changes in land uses and land values should not be attributed to the reduction in flooding per se.

Present flood damage-discharge relationships

In order to determine the effects of various alternative water resources systems on reducing flood damages in the Meramec Basin, flood damage-discharge relationships were developed for various river reaches in the basin. Flood damage data had been collected by the Corps of Engineers in connection with the Corps investigation of the Meramec Basin in the 1940's. The Corps data related to land uses and prices in 1946. These data were adjusted for changes in land use since 1946 and for the elimination of non-recurring damages, such as those stemming from raised highways and increased protection of railroad embankments. The extensive data on land use in the flood plains, compiled by the Meramec Basin Research Project, were utilized in modifying the Corps data. Most changes in the interim period have tended to reduce flood damages, but some -- such as the construction of new homes in the flood plain, have tended to increase damages for any given discharge, in comparison with 1946 conditions.

The wholesale price index for all commodities was used in changing 1946 dollars to 1959 dollars. The wholesale price index in 1946 was 78.7, in December 1959, 118.9.[11]

Thus data on recurring damages under essentially present -- 1959 -- conditions were obtained. Damages were divided into four categories where applicable: (1) agriculture, subdivided into five seasonal periods; (2) property; (3) highways and railroads; and (4) gravel workings. Flood damage-discharge curves were developed for the following reaches of the Meramec River and its two main tributaries, the Big and Bourbeuse rivers.

River	Reach	Gaging Station
Meramec	1A (mile 0.0 - 14.0)	Eureka
Meramec	1B (mile 14.0 - 37.8)	Eureka
Meramec	2 (mile 37.8 - 63.4)	Robertsville
Meramec	3 (mile 63.4 - 107.5)	Sullivan
Big	1 (mile 0.0 - 22.6)	Byrnesville
Bourbeuse	1 (mile 0.0 - 31.6)	Union

Figures 5 and 6 illustrate the nature of the flood damage-discharge relationships. Similar curves were developed for other reaches, and these were used to calculate flood damages over a 50-year period using synthetically generated hydrologic sequences of flooding as well as the historical trace (as explained later).

Future flood damage-discharge relationships

Because increased development in the Meramec Basin outside the St. Louis Metropolitan Area is likely to occur around present population concentrations -- which are located on ridges and uplands, and because the expanding St. Louis Metropolitan Area is likely to have an impact only on the lower portion of the Meramec Basin in the next 50 years -- in terms of increased demand for land, no changes were assumed in the flood-damage discharge relationships for any of the reaches, except for Reach 1B (Fenton to Eureka) of the Meramec River. Reach 1A, comprising the section of the Meramec River downstream from Fenton to the mouth of the river, is the main reach affected by flooding from Mississippi backwater.[12] Hence little development is anticipated in this area.

FLOOD DAMAGE - DISCHARGE RELATIONSHIPS, PRESENT CONDITIONS (1959)
MERAMEC RIVER, REACH 2. (Mile 37.8 - Mile 63.4)

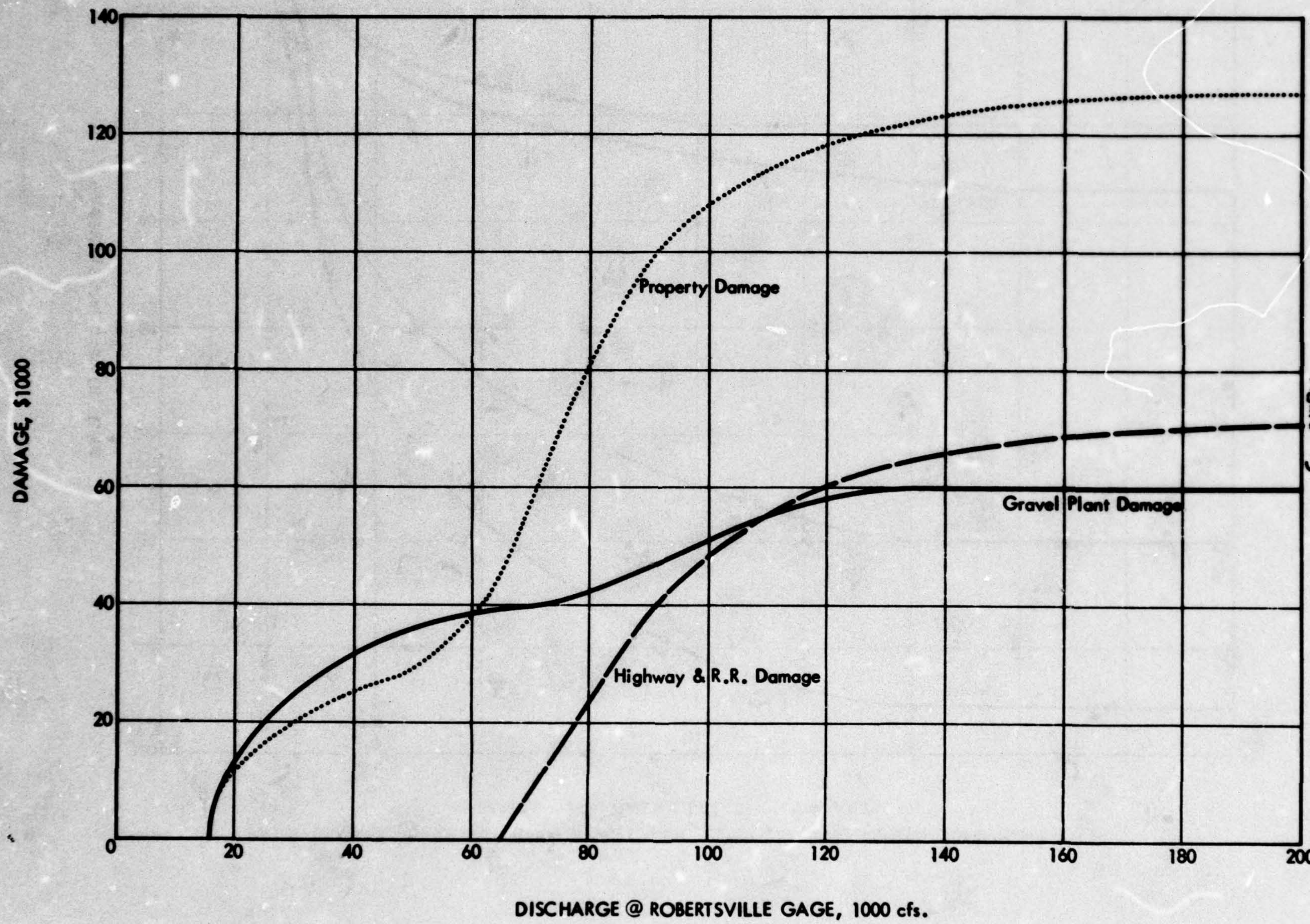


Figure 5

FLOOD DAMAGE - DISCHARGE RELATIONSHIPS, AGRICULTURAL DAMAGE, PRESENT CONDITIONS (1959)
MERAMEC RIVER, REACH 2. (Mile 37.8 - Mile 63.4)

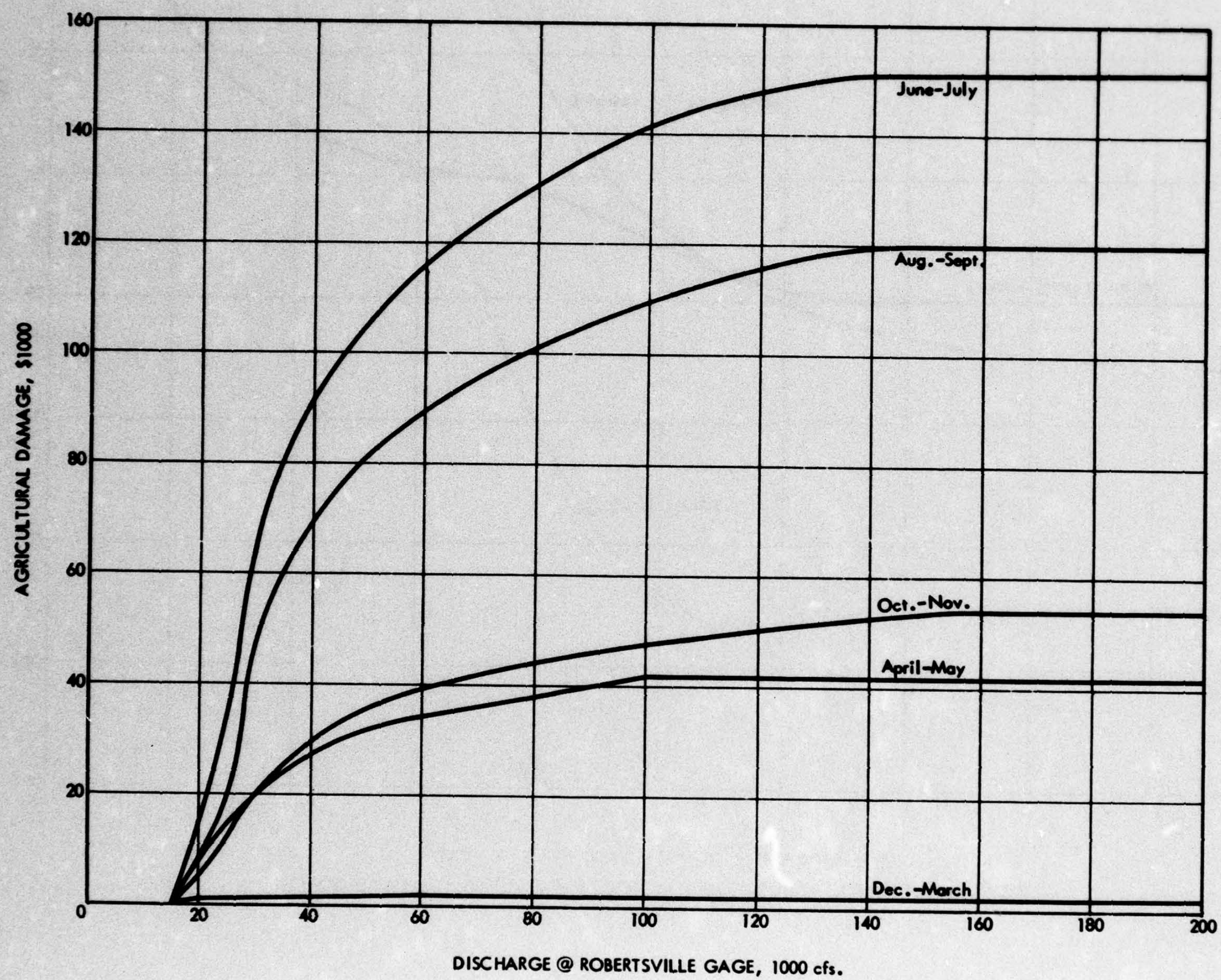


Figure 6

Future Flood Damage-Discharge Relationships, Reach 1B

Future land use without zoning or streamflow regulation

For Reach 1B, changes in future land use were estimated under various assumed conditions. The corresponding flood damage-discharge relationships (curves) are shown in Figure 7, along with the present relationship. No changes in damages to highways, railroads, gravel operations, and agricultural damages were estimated to occur. Since the Interstate Highway System in this area is not likely to be changed over the 50-year planning period, and since the railroads have raised their tracks and modified their embankments, this assumption appears reasonable. With respect to agricultural damages, even if demands for urban land were to expand greatly, little agricultural acreage would be lost to urban uses. Hence, given the likelihood that the pattern of farming in the area will not change much, the agricultural damage-discharge relationships were assumed to remain the same.

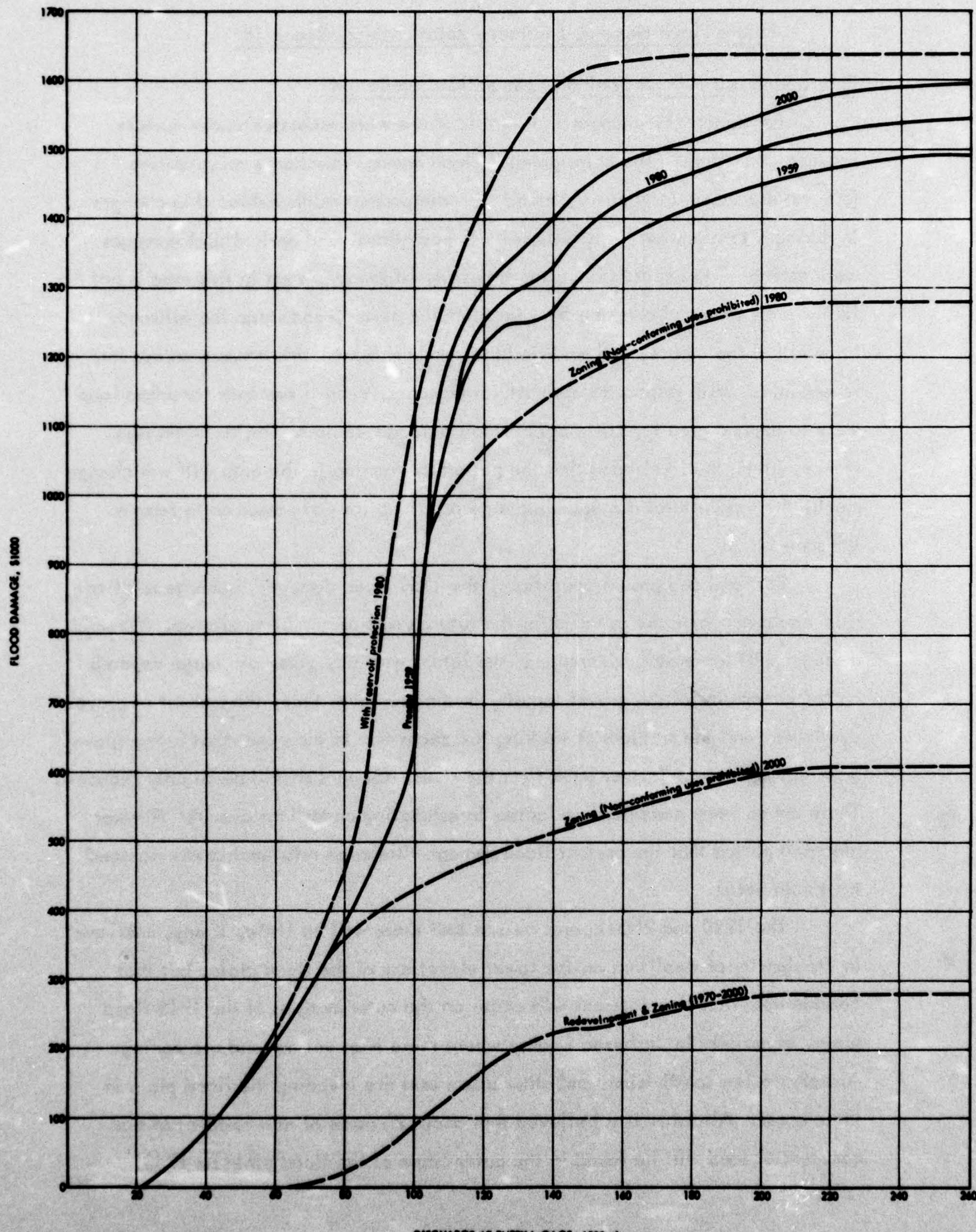
For sand and gravel operations, the 1959 flood damage-discharge relationship would appear to be as valid for the future years as can be predicted. Whether damages will increase or decrease in the future with any given discharge depends on the economics of the gravel industry in the area over time, the amount of gravel available, and the methods of working the deposits. In the event that future gravel workings take place farther back from the river, damages should be slightly reduced. There are so many complicating factors in estimating conditions over the 50-year planning period that the present flood damage-discharge relationship was assumed to remain valid.

The 1980 and 2000 curves assume that there will be little, if any, increase in the density of dwellings on the lower elevations of the flood plain, but that considerable new development will occur on the outer margins of the 1915 flood plain, especially in Jefferson County where there is as yet no land use zoning. Already, a few subdivisions and other urban uses are invading the flood plain in these areas. All told, it is believed that about 20 acres of new residential and commercial land will be found in the outer edges of the flood plain by 1980.

Figure 7

FLOOD DAMAGE - DISCHARGE RELATIONSHIPS, PRESENT & FUTURE CONDITIONS, MERAMEC RIVER, REACH I B. (Mile 14.0- Mile 37.8)

Property damage only



Assuming a damage of approximately $2,000 an acre for such land (empirically derived), about $40,000 more damages to property at a discharge of 175,000 cfs (the highest recorded flood, 1915) would occur in 1980 than in 1959. The rate of urban occupancy of the flood plain is expected to increase somewhat faster between 1980 and 2000 than between 1959 and 1980, resulting in a further increase in damages for the 2000 curve. Club house damages will probably remain largely unchanged in the future, and hence the lower portions of the 1959 curve remain unaltered. In fact, it might be argued that damages to club houses may diminish in the future when the economic lives of such structures are ended, and as new alternatives for such recreational use are made available elsewhere.

Flood damages with flood plain zoning

The curves labeled "Zoning 1980" and "Zoning 2000" are based on the assumptions that the entire flood plain in this reach will be zoned against "unwise use" and that flood damage-prone structures will not be allowed on the flood plain. These curves are based on the further assumption that the nonconforming uses, such as residential, which currently exist will gradually be eliminated as the economic lives of the present facilities expire. By 2000 over one-half of these currently nonconforming uses should be eliminated. Unfortunately, the type of flood plain occupant suffering the largest unit flood damages, i.e., industry, will probably still be in operation even under such a flood plain zoning plan.

Flood damages with redevelopment

The curve labeled "Redevelopment and Zoning" is based on the assumption that property flood damages in Reach 1B could be avoided almost entirely, or at least restricted to damages of the magnitude resulting from the 1947 flood, by actually removing nonconforming and flood damage-prone uses from the flood plain. Of course club houses, certain institutional uses such as recreation, and perhaps some industry might remain and therefore some flood damage would continue to occur.

The costs of such a redevelopment program for the area from Fenton to Times Beach are estimated to be as follows:

Area	Number of Dwellings	Redevelopment Cost[13]
Fenton	155	$1,600,000
Valley Park	350	6,000,000
Times Beach	220	1,700,000
Eureka	20	200,000
Relocation costs	---	1,500,000
		11,000,000
Minus salvage value		-1,000,000
Total net redevelopment costs		10,000,000[13]

This estimate does not include utilities or industries. Moreover, only those areas which receive the majority of flood damages are redeveloped and then zoned against further intensive use. It is assumed, however, that all remaining parts of the flood plain would be adequately zoned to prevent excessive damages in future floods. Damages to highways and railroads would remain essentially the same under this program.

Redevelopment is assumed to take ten years. The redevelopment costs, i.e., capital costs, are assumed to be spread evenly over the ten-year period. Annual administrative costs for the program are estimated to be about $20,000.

Flood damages with major reservoirs

The curve labeled "With reservoir protection"[14] is based on the assumption that one or more major water impoundment will be constructed in the basin. Assuming that the reservoir(s) would lower the frequency and amount of flooding in the lower Meramec River area, the intensity of land use would increase in the downstream areas, if there is a latent demand for such land. The amount of property damage which would occur with any given discharge if floods were not reduced would consequently be increased.

If it is assumed that the reduction in discharges would result in a residential density in the flood plain equal to the residential density presently existing on either side of the flood plain as revealed by the residential cross sections,[15] about 1,200 new homes would be added to the flood plain in this area by 1980. Assuming an average

damage of $400 per home (empirically derived), then a flood of 1915 proportions without regulation would cause an additional $500,000 damage, or one-third more damage than would presently occur with such a discharge. These assumptions are used to derive the "With reservoir protection" flood damage-discharge relationship. The result is probably a conservative estimate, as new industrial and commercial development might also occur. On the other hand, the 300 acres of industry that might develop would undoubtedly be located at or above levels corresponding to a discharge of 130,000 cfs. A discharge of such magnitude would be a rare occurrence with a major impoundment upstream. Therefore the curve as shown appears reasonable.[16]

No additional changes were made in the flood damage-discharge relation for 2000-2010 under the above assumption. It is doubtful that flood plain density, and hence flood damages, would change very much from 1980 to the end of the 50-year period. Future urban land use density in this general area will very likely be much lower than at present, and would not be expected to exceed, by much, present subdivision densities in this area. It is assumed that this density will almost be reached by 1980 if a reservoir is, or reservoirs are, constructed to regulate flood flows.

Amount of present flood damages

As explained in the Hydrology appendix, the future amount of flood damages has been estimated on the basis of probable occurrence of floods in the future. Two methods can be used: (1) assuming that the historic record (in this case a 40-year period) will prevail in the future; (2) generating synthetic hydrology, which by statistical methods calculates the occurrence of floods based on a probabilistic expansion of the 40-year actual record into a 500-year period. This 500-year synthetic period has been used by the Meramec Basin Research Project and has been divided into 50-year cycles (to coincide with the 50-year planning period); flood occurrences and associated flood damages derived from the damage discharge curves[17] have been calculated for five 50-year periods. The results of these flood damage calculations for the Meramec Basin are shown in Table 3.

Table 3

AVERAGE ANNUAL FLOOD DAMAGES IN THE MERAMEC BASIN[a]

	1 Unmodified (without protection)	2 Modified by 3-reservoir system	3 Benefits from 3-reservoir system
Synthetic trace No. 1	$343,000	43,000	298,000
Synthetic trace No. 2	357,000	87,000	270,000
Synthetic trace No. 3	426,000	152,000	274,000
Synthetic trace No. 4	378,000	59,000	319,000
Synthetic trace No. 5	480,000	85,000	395,000
Average	397,000	86,000	311,000
Historic trace (actual record)	353,000	46,000	307,000

[a]In reaches of the Meramec, Bourbeuse, and Big Rivers downstream from the three dams proposed by the Corps of Engineers in 1949.

In the analysis of various alternatives made by the Project, an average annual damage of $397,000 (rounded to $400,000) has been used. This is some $45,000 greater than damages derived from the historic trace. The synthetic trace, although not differing a great deal, appears to be a more precise way of looking into the future. The figure of $397,000 is simply an estimate derived from synthetic calculations, based on previous Corps of Engineers damage-discharge calculations and adjusted for changes in dollar value and intensity of development since that time.

The Corps in their 1948 report estimated $503,000 annual damages. This of necessity was based on a shorter record than now available and apparently included the 1915 flood, 175,000 cfs (the highest known) and ended with the 1945 flood, 130,000 cfs (the highest of official record). This combination of a shorter record and inclusion of the two highest floods gives a higher figure. In addition, their method of calculation differed. Converting the Corps figure to 1960 dollars

and allowing some increase in damage because of greater property development might produce a current figure of about $800,000 average annual damages -- twice our figure.

Additional flood damages occur on the smaller tributaries, especially in the St. Louis Metropolitan Area, and on the major basin rivers upstream from the three dams. The amount of these damages has not been accurately determined, but is probably of the same order of magnitude as main-stem damages.

Reducing Flood Damage in the Meramec Basin

Various water resources systems in the Meramec Basin were investigated with respect to their effects on flood damage reduction. The assumptions made in these investigations are set forth in Appendix B.

Operation studies indicate that approximately 80% of the flood damages which now occur in the reaches of the rivers below the three dams proposed by the Corps of Engineers in 1949 could have been prevented by these three dams (Table 3). The average annual flood damage reduction benefits attributable to the three reservoir system is therefore slightly over $300,000. A small additional amount would accrue from flood damage reduction on the Mississippi River. The flood damage reduction benefits attributable to the alternative reservoirs proposed in Volume I have been calculated as a proportion of the three-dam benefits -- the benefits being proportional to the damage in each reach, modified by the percent of the drainage area of that reach controlled by a particular reservoir, and adjusted for the amount of flood run-off which could be stored in a particular reservoir.

Although benefits from flood damage reduction alone are not sufficient to cover the costs of reservoir construction and operation, the construction of a reservoir or reservoirs primarily to satisfy the demand for water recreation would also serve to provide some degree of flood protection. However, "complete" protection does not appear to be economically feasible. Therefore it is important that additional flood damage reduction measures be undertaken. (These additional methods should not be limited to situations in which reservoirs cannot be justified, but rather should be considered part of the total flood damage reduction package.) Improvement of

the flood warning system would be helpful in reducing damages, particularly to movable property. Flood plain zoning and channel encroachment legislation would prevent unnecessary future increases in flood damage. Flood-proofing of structures already on the flood plain as well as possible new structures might be feasible and should be investigated more thoroughly. The preparation of flood frequency maps are a necessary first step for several of the preceeding measures as well as for a comprehensive flood insurance program. These maps should be prepared as soon as possible. Until the advent of a comprehensive flood insurance program it would be wise for flood plain users to establish a program of self-insurance (a contingency fund). An intensification of land-treatment programs would also be beneficial -- although the primary benefits of such programs would not be from reducing flood damages.

Flood damages are a problem, but not a major one. A broad program of flood damage reduction including reservoir construction in conjunction with other measures would contribute to alleviating the problem.

REFERENCES AND NOTES

1. Methods of reducing flood damage are discussed in William Hoyt and Walter Langbein, Floods, Princeton University Press, Princeton, 1954, and Gilbert F. White, Human Adjustment to Floods, University of Chicago, Department of Geography Research Paper No. 29, Chicago, 1942.

2. Francis C. Murphy, Regulating Flood-Plain Development, University of Chicago, Department of Geography Research Paper No. 56, Chicago, 1958.

3. U. S. Weather Bureau, River Forecasting and Hydrometeorological Analysis, U. S. Senate Select Committee on National Water Resources, Committee Print No. 25, Washington, 1959.

4. Luna Leopold and Thomas Maddock, The Flood Control Controversy: Big Dams, Little Dams, and Land Management, (Sponsored by the Conservation Foundation), Ronald Press Co., New York, 1953.

5. E. A. Coleman, Vegetation and Watershed Management, (Sponsored by the Conservation Foundation), Ronald Press Co., New York, 1953.

6. These costs are based on estimates made by Walter Eschbach, Senior Planner of the St. Louis County Planning Commission.

7. The "river induced" structures represent, in general, recreational facilities rather than permanent residences.

8. "Changing Industrial Patterns in Metropolitan St. Louis and the Demand and Supply of Industrial Land to 1980," (separate appendix).

9. See St. Louis County Planning Commission, Guide for Growth, Clayton, 1961, and Statement by the St. Louis County Planning Commission on Use of Meramec River Basin, for Public Hearing by District Engineer, U. S. Army, at St. Clair, Missouri, April 7, 1961.

10. Otto Echstein, Water-Resource Development, Harvard University Press, Cambridge, 1958, 129-132. As Sheaffer puts it: "It is believed that many of the so-called lost profits constitute in reality postponed profits." John R. Sheaffer, Flood Proofing: An Element in a Flood Damage Reduction Program, Department of Geography, Research Paper No. 65, University of Chicago, Chicago, 1960, 95.

11. U. S. Department of Commerce, Statistical Abstract of the United States 1960, Washington, 1960, 331. Sheaffer, ibid., also used this index to up-date flood damage data. Since flood damages generally involve all commodities, many of which have not yet been retailed, the use of the wholesale index for all commodities seems reasonable.

REFERENCES AND NOTES (continued)

12. See the discussion of flooding in the lower Meramec River in separate appendix, "Flooding in the Lower Meramec River."

13. These costs are based on estimates made by Walter Eschbach, Senior Planner, St. Louis County Planning Commission.

14. See Figures 2 and 3.

15. Note that flood damage reduction benefits of the second type, i.e., more intensive land use stemming from flow regulation, are implicit in this curve.

16. See for example, Tennessee Valley Authority, Flood Problems and Management in the Tennessee River Basin, Committee Print No. 16, Senate Select Committee on National Water Resources, Washington, 1960, 18. The authority estimated that for every community in the valley for which structures can be economically justified there are 20 communities where such structures cannot be justified.

17. Figures 5, 6, and 7 are examples.

APPENDIX A

FLOOD-PLAIN LAND VALUES

In order to evaluate the nature and extent of flood damages in the Meramec Basin, an attempt was made to determine the value of the land and structures located in the flood plain of the lower Meramec Basin. Several different approaches were tried.

All land sales which occurred in or near the flood plain in St. Louis County for the period August, 1957 (date of last major flood) through 1959, were obtained from warranty deeds. Each sale was located on base maps as determined by the legal descriptions on the deeds, and the sale price was estimated by use of the attached Federal Revenue Stamp. Deeds bearing no stamps, as well as all intrafamily sales were eliminated. From these data the value per acre for many different types of land use was determined. The 113 sales occurring in the flood plain during this period accounted for 2.7% of the flood-plain land area. Unfortunately all but 26 of these sales occurred in the incorporated areas, such as Valley Park and Times Beach.

It was found that the mixture and intensity of land use in the 14,183 acres of flood-plain land located in St. Louis County varied considerably from one area to another. Consequently several areas were segregated for individual analysis: (1) the incorporated residential communities of Valley Park and Times Beach; (2) the more intensively used land near major transportation arteries crossing the Meramec River; (3) the more remote lower-valued agricultural, forested, and vacant land in the interstices between the major routes; and (4) public utilities, roads, railroads, and bridges. Using this classification, a first approximation to the present total value of the flood plain in St. Louis County, including both land and buildings, is about $24,000,000. The computation is shown in Table 4. It must be emphasized, however, that this is only an estimate based on a gross land use type classification, and may be five or more million dollars off in either direction. Moreover this is not the <u>land value</u>, but the total land and property value. Nevertheless from such a gross value, an estimate of the order of magnitude of the value of the flood-plain land itself can be obtained.

Table 4

PRESENT VALUE OF LAND AND STRUCTURES IN THE MERAMEC RIVER FLOOD PLAIN IN ST. LOUIS COUNTY[a]

Place or item	Acres	Unit Value (dollar per acre)	Value (dollars)
Times Beach	377	$ 9,300	$3,500,000
Valley Park	317	11,900	3,800,000
Roads	432[b]	--	1,000,000
Railroads	237[c]	--	2,500,000
Utilities, etc.	139	2,000	300,000
Other, good access	3,200	1,600	5,100,000
Other, poor access	9,481	800[d]	7,600,000
TOTAL	14,183		23,800,000

[a] Includes area inundated by 1915 flood. Value determined from an examination of warranty deed sales, August, 1957 through 1959.

[b] Includes 7.4 miles of state roads, 14.4 miles of county roads, and 24.7 miles of incorporated roads.

[c] Includes 20 miles of railroad.

[d] Determined by dividing the accumulated total value of sales by the accumulated non-incorporated land acres.

A check on the estimate in Table 4 was made using average values for specific types of land use. The types of land use in the St. Louis County flood plain were determined from data of the St. Louis County Planning Commission. This method, as shown in Table 5, produced figures almost identical with the first estimate of gross value of the flood plain, including land and buildings.

A further demonstration of the validity of the above total value of the St. Louis County flood plain is indicated by the calculation made by Walter Eschbach of the St. Louis County Planning Commission,[1] who estimated the total value of land and structures to be approximately $20,000,000. This figure was obtained by a more detailed land use inventory than above, whereby average land values per acre were assigned to the different land use types. Unfortunately, the specific values assigned by Eschbach to the various land uses are not available. Even though the Planning Commission Report did not include public utilities, roads, bridges, and railroads in the calculations, the three estimates of total value are close.

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[1] Walter Eschbach, Statistical Analysis of the Meramec River Flood Plain in St. Louis County, St. Louis County Planning Commission, Clayton, unpublished, 1960.

Table 5

PRESENT VALUE OF THE MERAMEC RIVER FLOOD PLAIN IN ST. LOUIS COUNTY, AS DETERMINED BY AVERAGE VALUES FOR SPECIFIC TYPES OF LAND USE[a]

Land use	Acres or units	Unit Value (dollar per acre or unit)	Value (dollars)
Vacant	1,805 acres	$ 500	$ 900,000
Resort (seasonal)	576 units	2,000	1,200,000
Resort (yearly)	568 units	4,000	2,300,000
Permanent residence	481 units	10,000	4,600,000
Recreation land	144 acres	800	100,000
Commercial	140 acres	3,000	400,000
Manufacturing	77 acres	5,000	400,000
Agriculture	7,840 acres	1,000	7,800,000
Woodland	2,719 acres	500	1,400,000
Sand and gravel	237 acres	3,000	700,000
Roads, bridges, railroads, utilities, etc.	808 acres	Variable	3,800,000
TOTAL			23,600,000

[a]Includes land and structures.

APPENDIX B

PROCEDURES USED IN OPERATION STUDIES

The assumptions made with respect to the effect of the various water resource systems on flood damage reduction in the Meramec Basin are as follows:

1. In all analyses of alternative systems, unmodified flood damages relating to specific discharges were obtained from the flood damage-discharge relationships as developed. For all river reaches except 1B, flood damages were assumed to remain the same over the period of analysis, as indicated previously. For Reach 1B, where development is most likely to occur, the 1959 relationship was used for the first ten years, the 1980 relationship for the next 20 years, and the 2000 relationship for the final 20 years.

2. In all analyses of alternative systems, agricultural flood damages from successive floods during the primary growing season, June to September inclusive, were modified to account for the effect of sequence of flooding. A relationship between (a) the ratio of the total number of acres flooded in the four months to the number of acres flooded in the maximum flood, and (b) the percent of unadjusted total damages, was used to determine the modification.

3. In the alternative system including only flood plain zoning and flood warning, it was assumed that the flood warning network proposed along with the associated flood plain zoning would achieve a net reduction of 10%[1] in all flood damages, other than agricultural damages and property damages in Reach 1B. With respect to Reach 1B, the change in property flood damages under conditions of flood plain zoning were indicated in the previous section. The net reduction allows for the costs of evacuation and reoccupancy but excludes the costs of the flood warning network and the preparation and administration of flood plain zoning regulations. These latter costs were estimated separately.

It was assumed that an expanded network of both precipitation gages and river staff gages would be installed in the basin, particularly on tributaries such as Courtois Creek, Indian Creek, Little Meramec River, Fox Creek, Grand Glaize Creek, and

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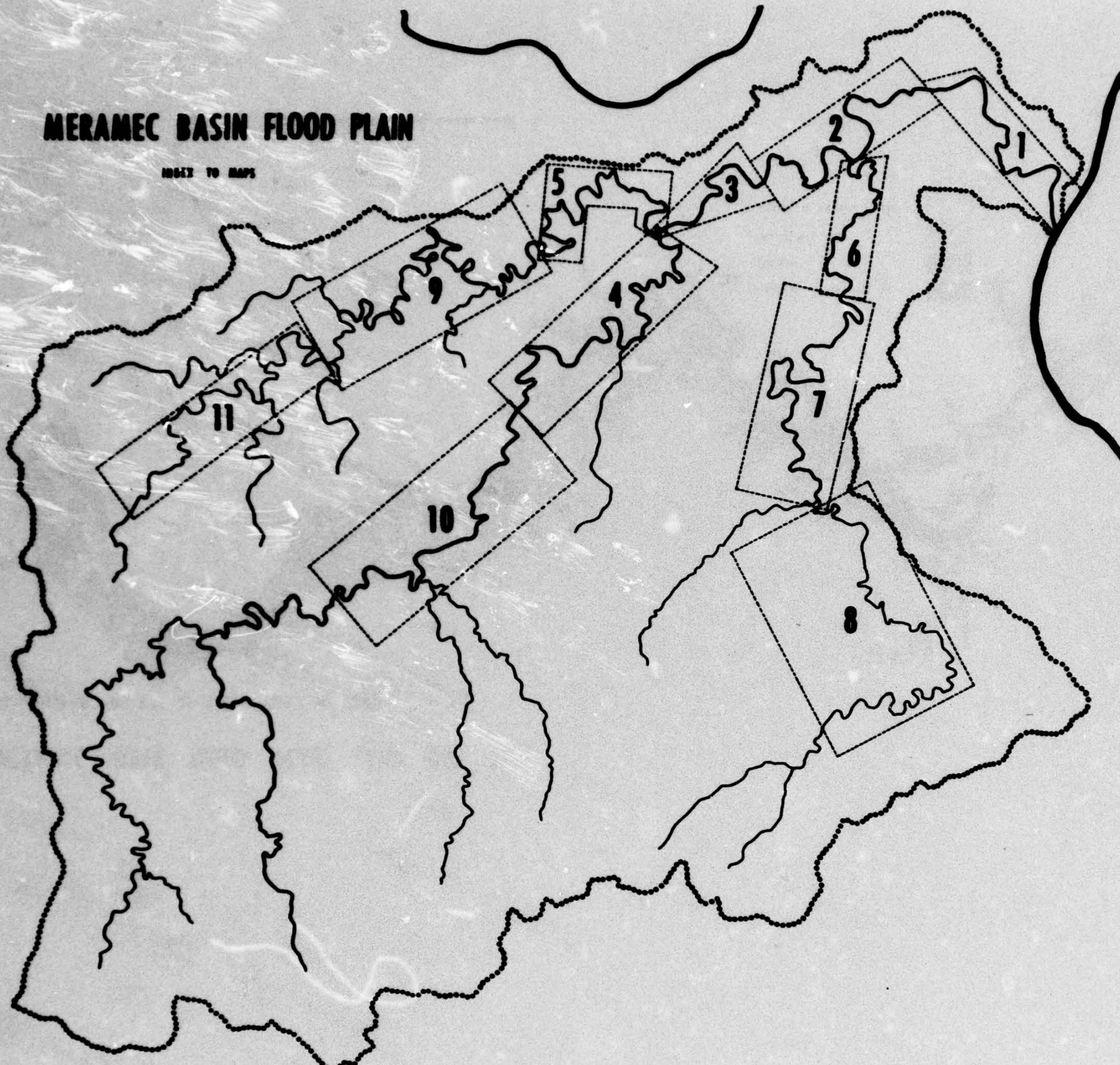
[1] U. S. Senate Select Committee on National Water Resources. River Forecasting and Hydrometeorological Analysis. Committee print No. 25 (prepared by the U.S. Weather Bureau), Washington, 1960.

so on, wherever such installations would be useful and do not now exist. The network of gages would be in addition to and integrated with the existing gages of the U.S. Weather Bureau. A system of reporting precipitation and gage heights to a central headquarters, and an outgoing system for communicating predicted river levels and warnings to evacuate would be established. The flood warning network would be operated in conjunction with the River Forecast Center of the Weather Bureau in St. Louis. The expanded network along with the radar installations of the Weather Bureau should make possible the achievement of the 10% reduction in flood damages.

4. For the system involving redevelopment in addition to a flood warning network and flood plain zoning, it was assumed that a net reduction of 10% in all flood damages except for agricultural damages and property damages in Reach 1B would be achieved. In Reach 1B, property flood damages corresponding to any given discharge were assumed to be reduced proportionately during the first ten years until the full redevelopment program had been accomplished. Then the relationship between flood damage and discharge was assumed to be as shown on the "Redevelopment" curve.

Capital and annual costs of the flood plain zoning and the flood warning network were assumed the same as in previous section.

5. In evaluating systems in which there was protection equivalent to the three reservoirs proposed in 1949, one each on the Big, Bourbeuse, and Meramec rivers, it was assumed that the flood warning network would not reduce flood damages over and above any reduction accomplished by the reservoirs. This underestimates by some amount the flood damage reduction benefits possible. No costs for the flood warning network were therefore included in system costs. It was assumed further that the flood plains below the reservoirs would be regulated so as to preclude development over and above present conditions, except in Reach 1B. Changes in the property flood damage-discharge relationship for Reach 1B have been described above, and include benefits from increased utilization of the flood plain.

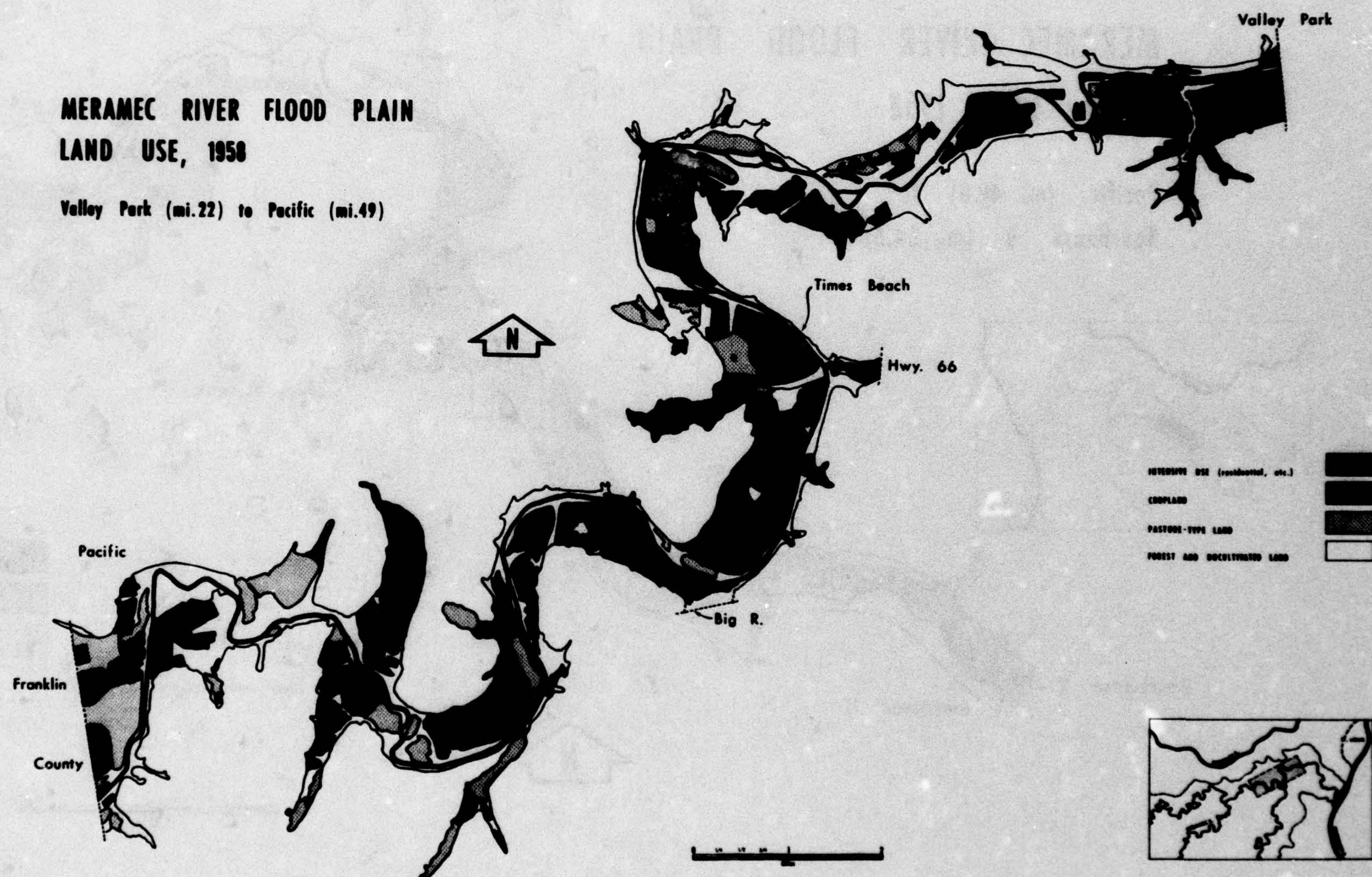

MERAMEC BASIN FLOOD PLAIN
INDEX TO MAPS
1
2
3
4
5
6
7
8
9
10
11

(1)

MERAMEC RIVER FLOOD PLAIN LAND USE, 1958

Mississippi R. (mi. 0.0) to Valley Park (mi. 22.0)

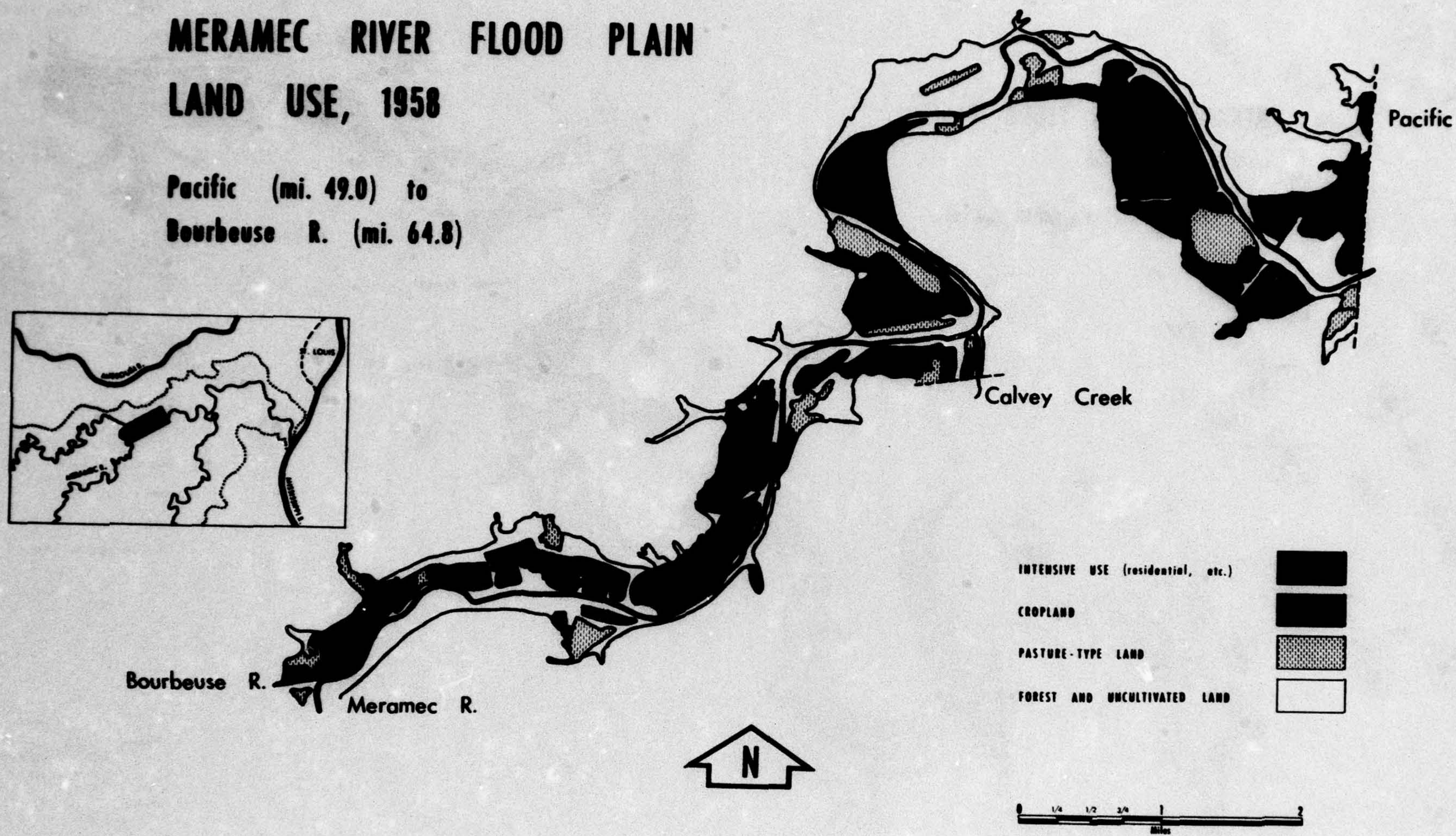
(2)


MERAMEC RIVER FLOOD PLAIN
LAND USE, 1958
Valley Park (mi.22) to Pacific (mi.49)
Valley Park
Times Beach
Hwy. 66
Big R.
Pacific
Franklin
County
INTENSIVE USE (residential, etc.)
CROPLAND
PASTURE-TYPE LAND
FOREST AND UNCULTIVATED LAND

(3)

MERAMEC RIVER FLOOD PLAIN
LAND USE, 1958

Pacific (mi. 49.0) to
Bourbeuse R. (mi. 64.8)



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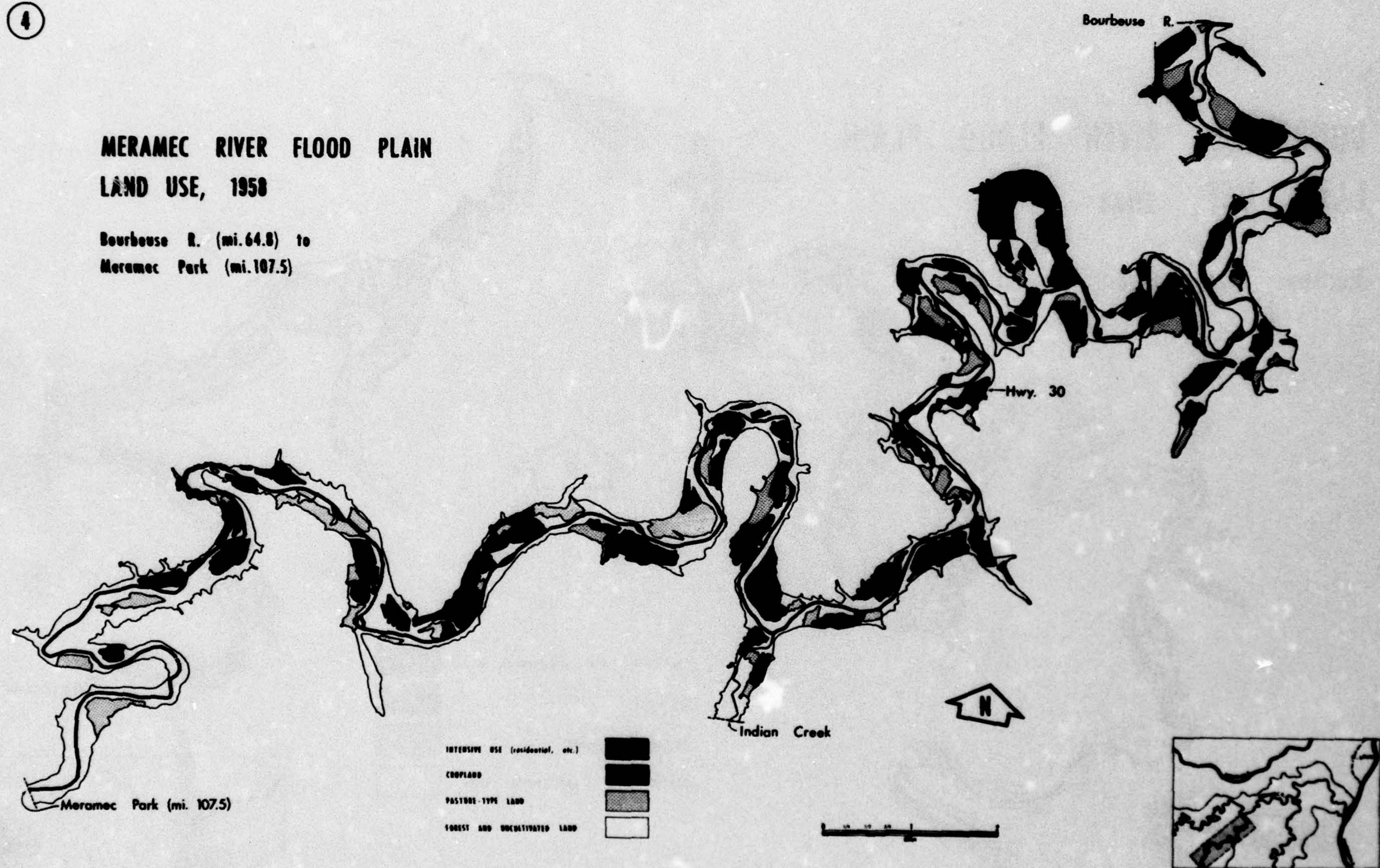
MERAMEC RIVER FLOOD PLAIN LAND USE, 1958

Bourbeuse R. (mi. 64.8) to
Meramec Park (mi. 107.5)



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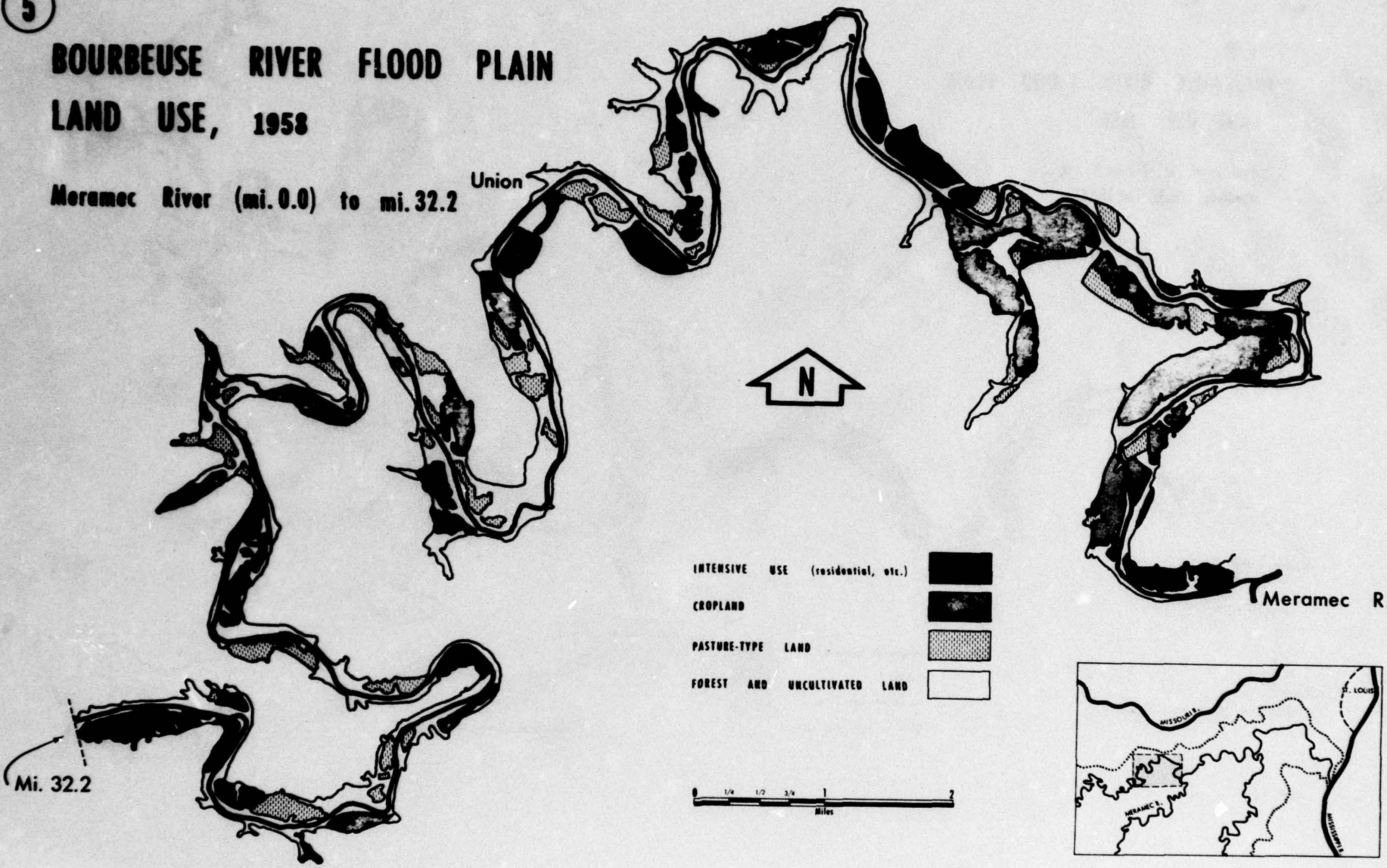
BOURBEUSE RIVER FLOOD PLAIN LAND USE, 1958

Meramec River (mi. 0.0) to mi. 32.2



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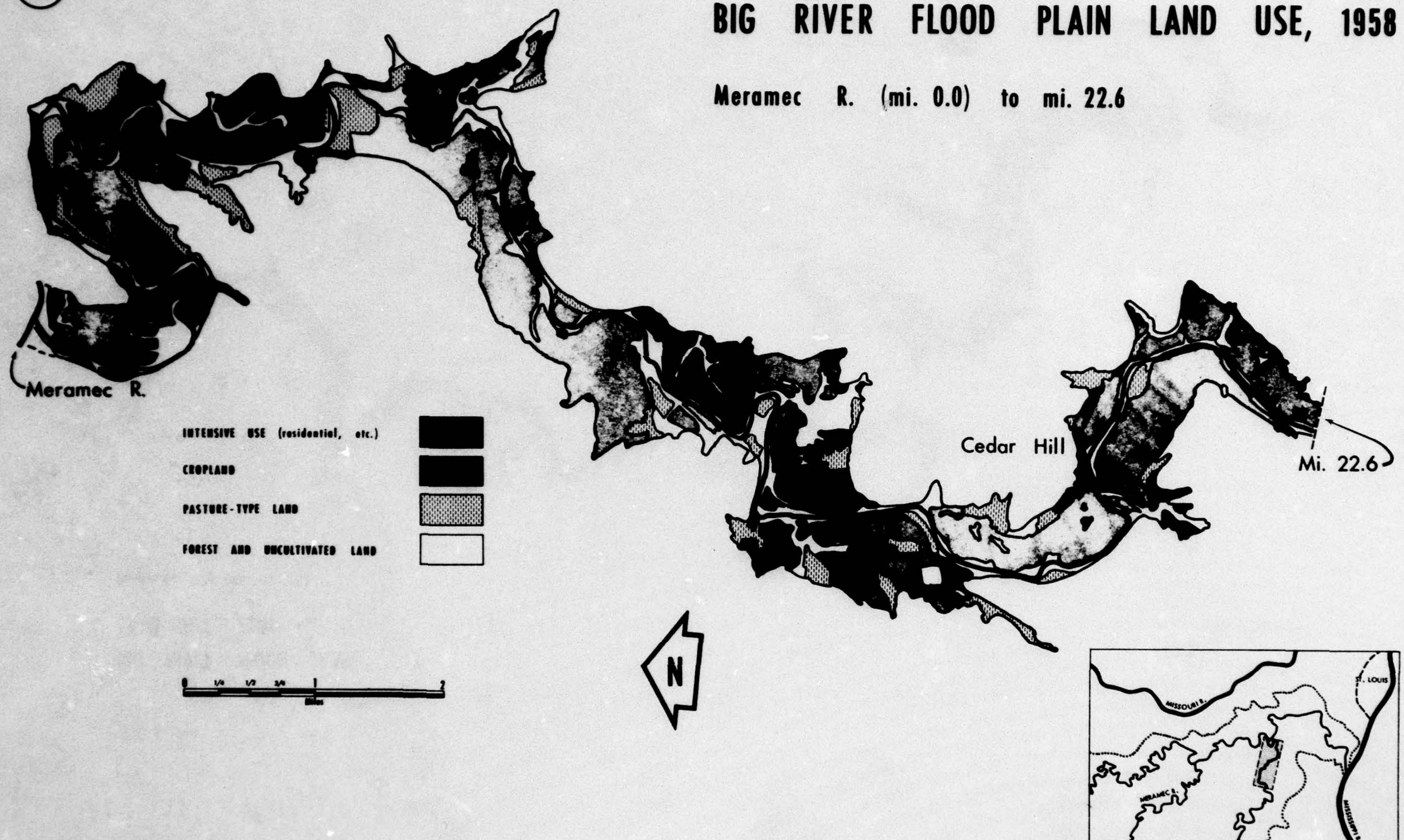
BIG RIVER FLOOD PLAIN LAND USE, 1958

Meramec R. (mi. 0.0) to mi. 22.6



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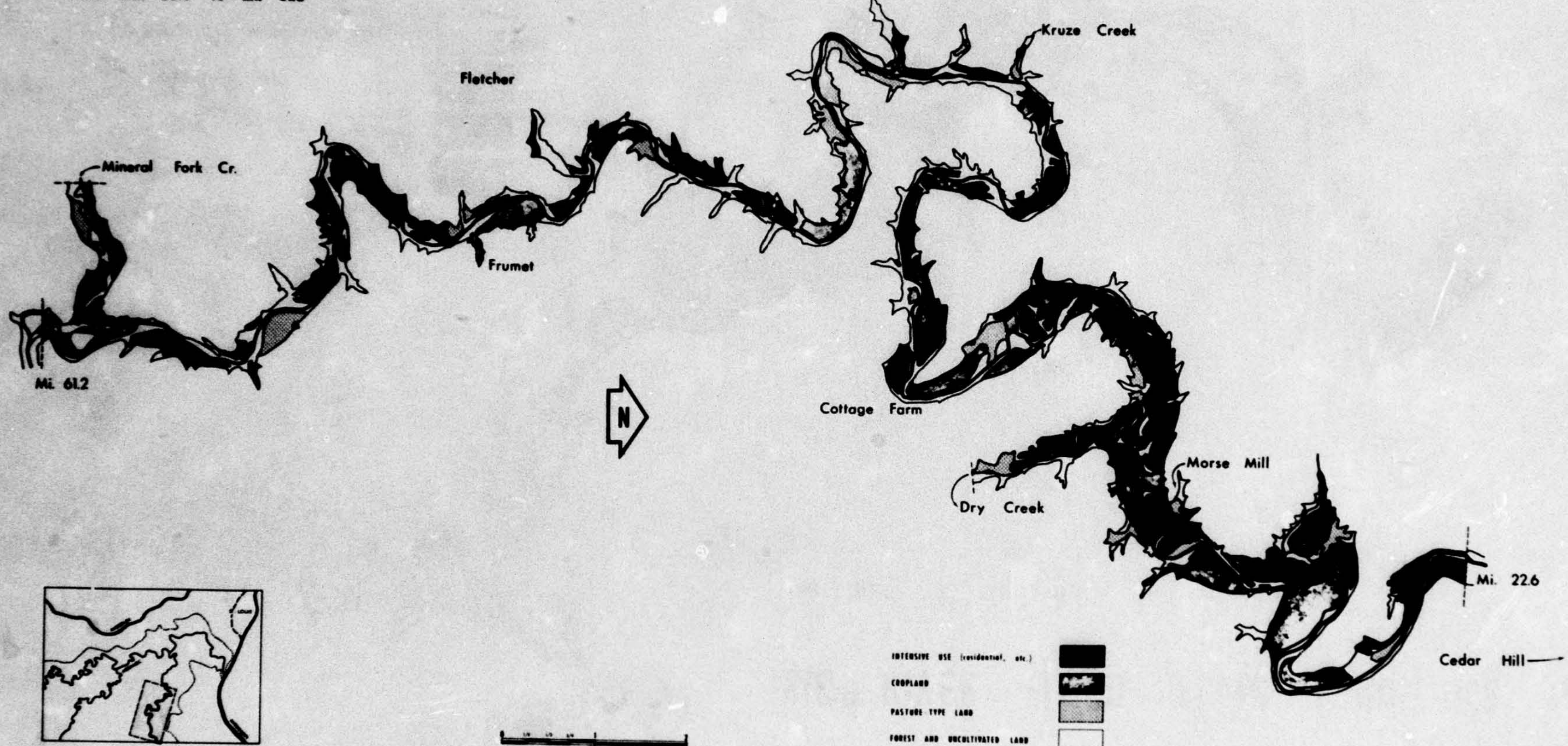
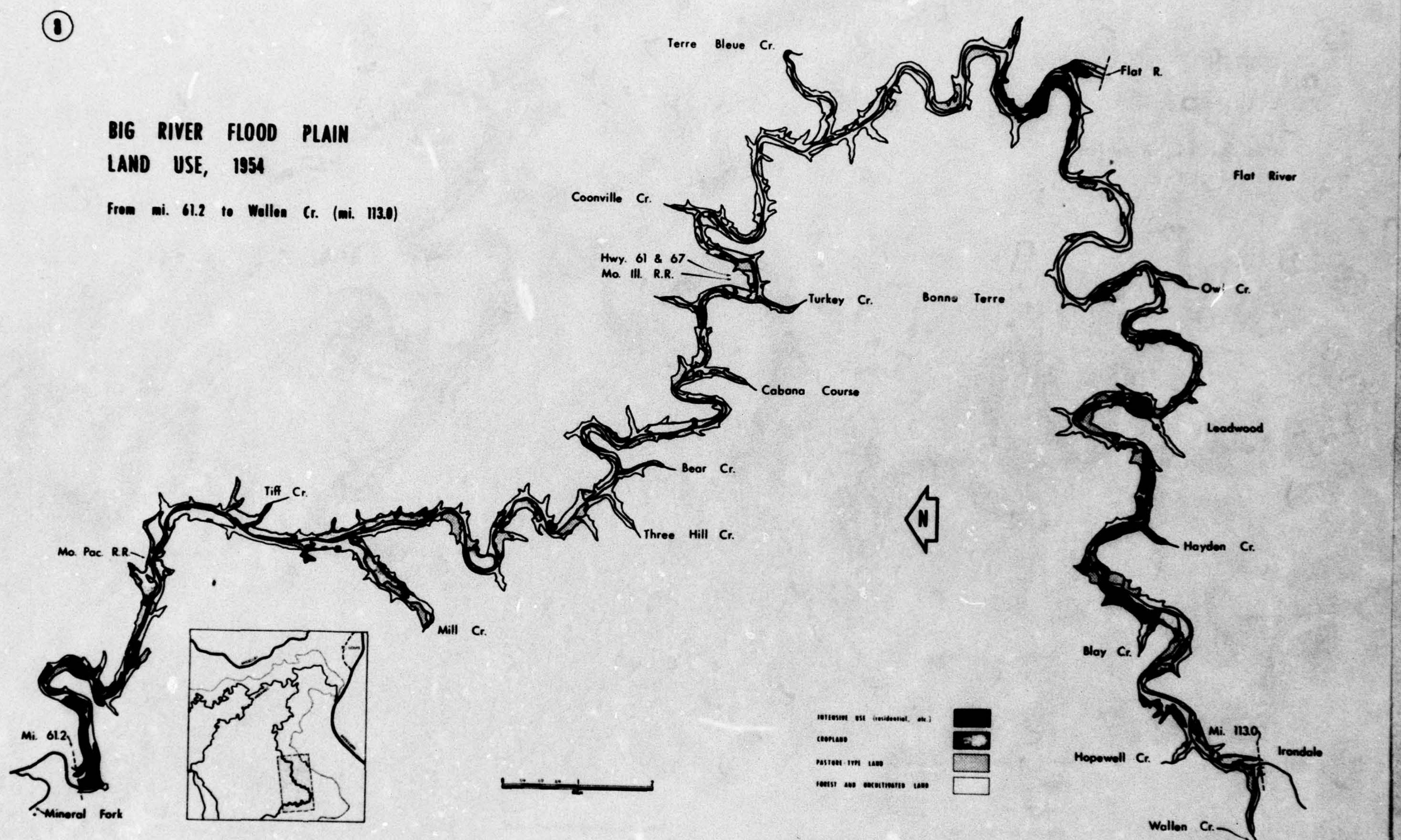
BIG RIVER FLOOD PLAIN
LAND USE, 1954

From mi. 22.6 to mi. 61.2

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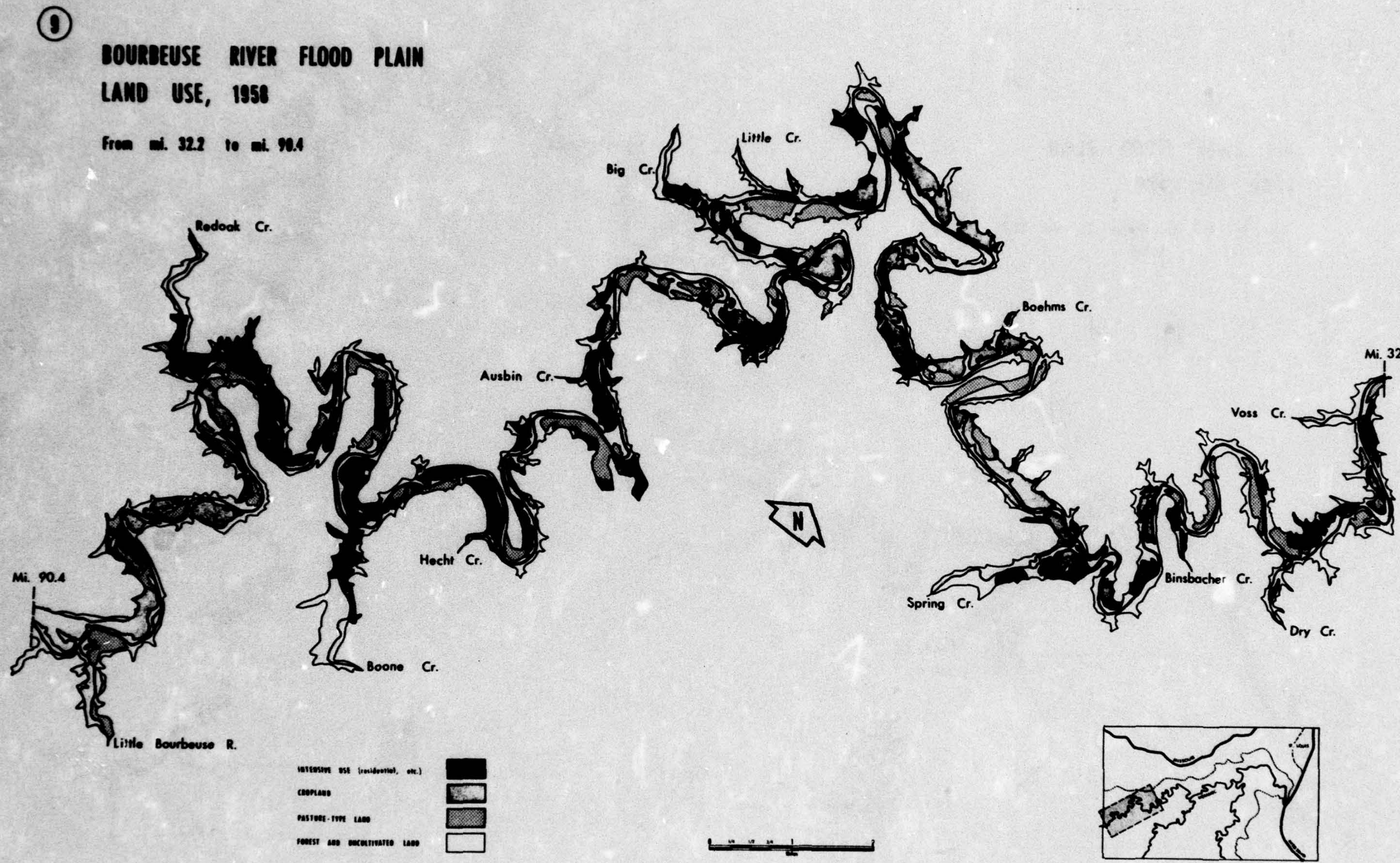
BIG RIVER FLOOD PLAIN
LAND USE, 1954
From mi. 61.2 to Wallen Cr. (mi. 113.0)
Terre Bleue Cr.
Flat R.
Flat River
Coonville Cr.
Hwy. 61 & 67
Mo. Ill. R.R.
Turkey Cr.
Bonne Terre
Owl Cr.
Cabana Course
Leadwood
Bear Cr.
Tiff Cr.
Three Hill Cr.
N
Hayden Cr.
Mo. Pac. R.R.
Mill Cr.
Blay Cr.
Mi. 61.2
Mi. 113.0
Irondale
Hopewell Cr.
Mineral Fork
Wallen Cr.
INTENSIVE USE (residential, etc.)
CROPLAND
PASTURE TYPE LAND
FOREST AND UNCULTIVATED LAND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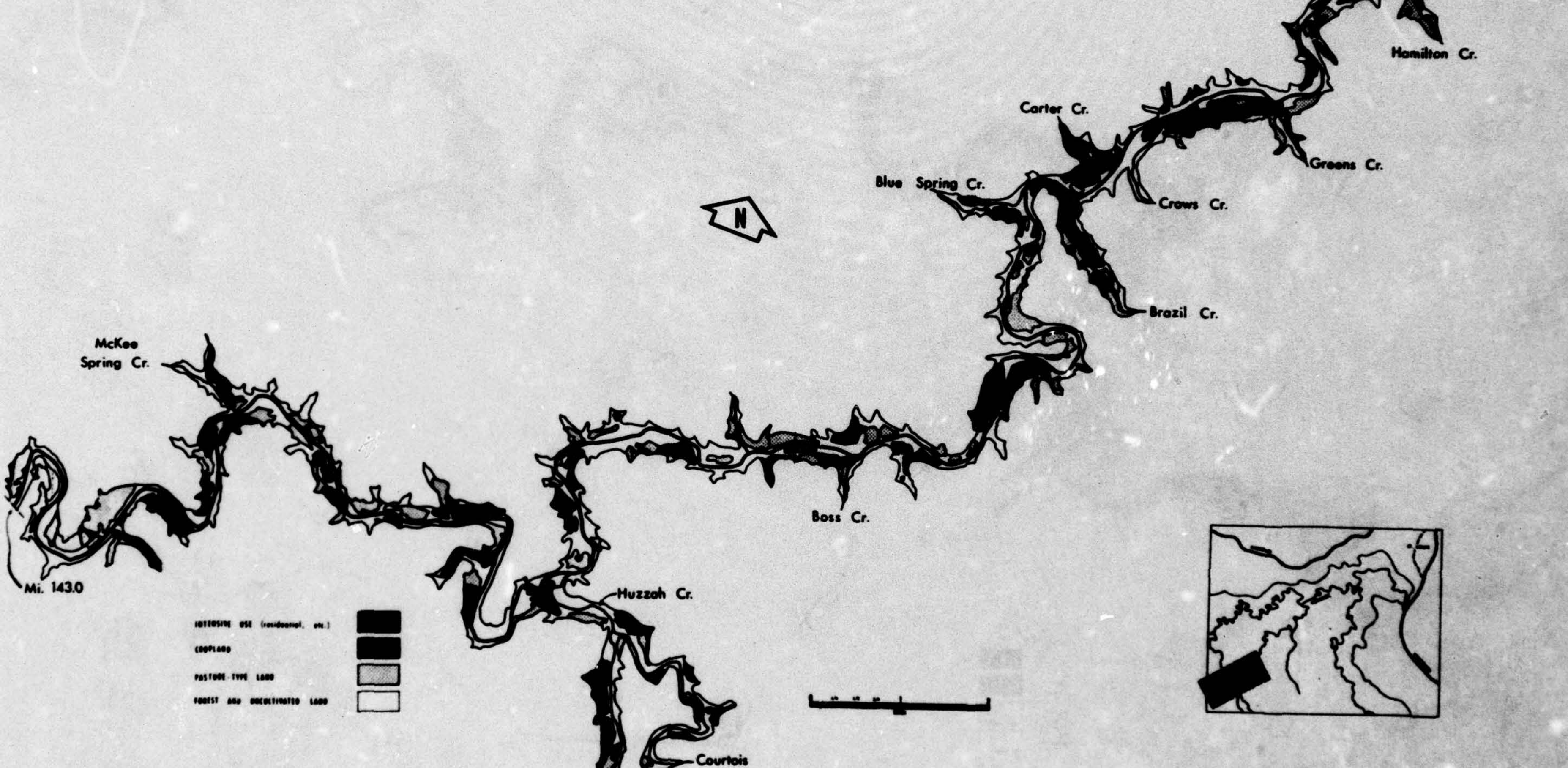
BOURBEUSE RIVER FLOOD PLAIN
LAND USE, 1958
From mi. 32.2 to mi. 90.4
Redoak Cr.
Big Cr.
Little Cr.
Ausbin Cr.
Boehms Cr.
Mi. 32.2
Voss Cr.
Hecht Cr.
N
Mi. 90.4
Spring Cr.
Binsbacher Cr.
Dry Cr.
Boone Cr.
Little Bourbeuse R.
INTENSIVE USE (residential, etc.)
CROPLAND
PASTURE-TYPE LAND
FOREST AND UNCULTIVATED LAND

⑩

MERAMEC RIVER FLOOD PLAIN LAND USE, 1958

Meramec Park (mi. 107.5) to mi. 143.0



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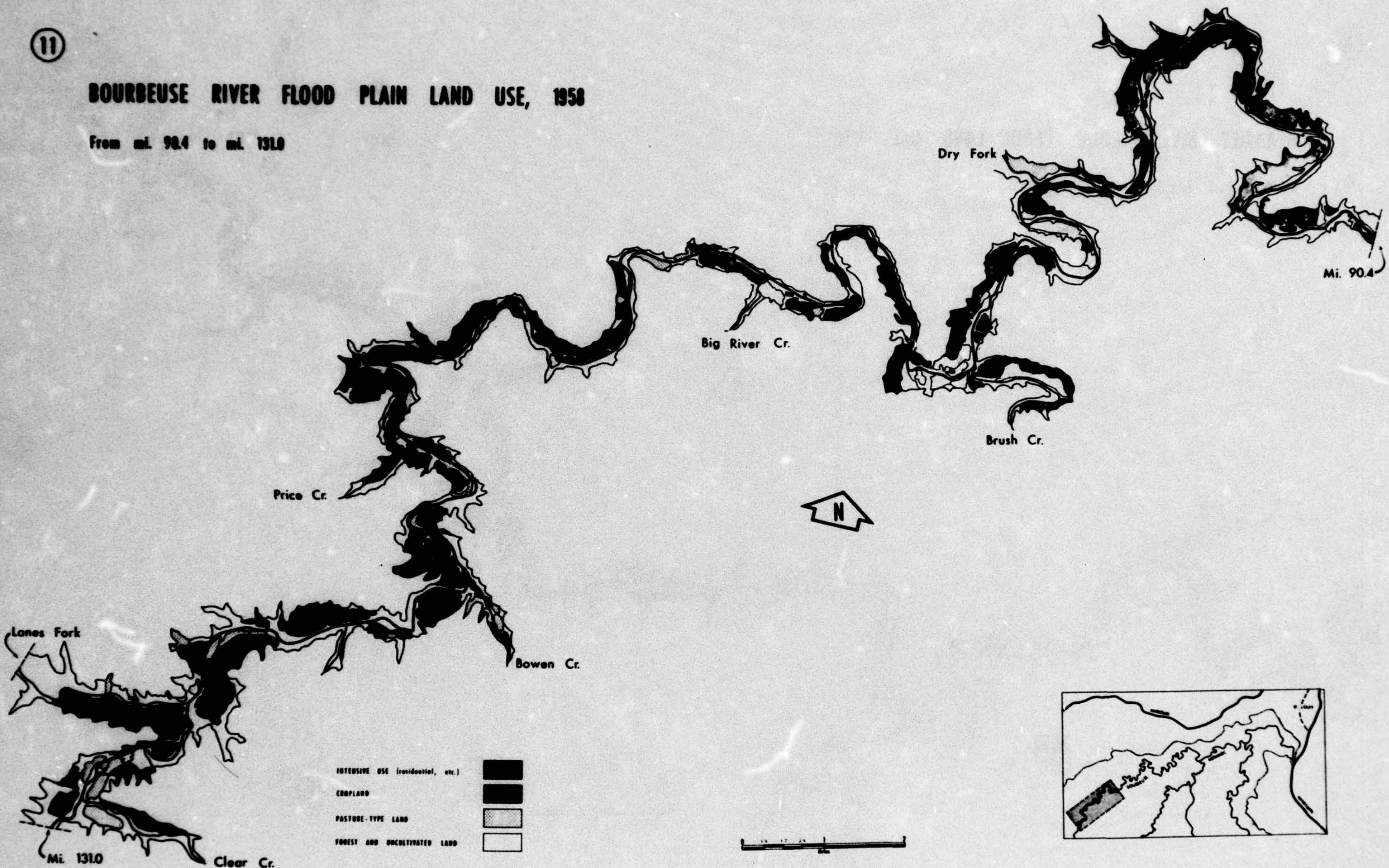
BOURBEUSE RIVER FLOOD PLAIN LAND USE, 1958

From mi. 90.4 to mi. 131.0



THE MERAMEC BASIN

Volume III
Water Needs and Problems

Chapter 3
MUNICIPAL AND INDUSTRIAL WATER SUPPLY

Meramec Basin Research Project
Washington University
St. Louis, Missouri
December 1961

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MUNICIPAL AND INDUSTRIAL WATER SUPPLY

<u>Summary</u>

The Meramec Basin is blessed with generally ample precipitation. The climate is classified as humid. Rainfall during the growing season is adequate during most years and the use of water for irrigation is consequently not large. The supply of water for municipal and industrial purposes within the basin is relatively abundant in relation to present and potential demands. There are three sources of supply: (1) ground water from deep bedrock or shallow residual soil aquifers, (2) water from surface streams, and (3) ground water from the alluvial material bordering the surface streams. All of the water used in the upper basin is supplied from deep underground sources; only in the lower basin is any use made of surface water or alluvial ground water. This is made necessary by the larger demand in the lower basin coupled with the fact that deep ground water in the lower basin contains large amounts of dissolved minerals and is unusable without extensive treatment. Since there are no heavy water-using industries within the Meramec Basin, and only one or two cities in the upper basin whose population exceeds 5,000 persons, all of the water needs of that portion of the basin outside the St. Louis area can be met from underground sources -- both at the present time and in the foreseeable future. Only in small local areas may difficulties arise with regard to the quality or amount of deep ground water.

Only one area in or near the Meramec Basin requires large quantities of water -- the St. Louis Metropolitan Area. Ample quantities of surface water are available to supply this need from the combined flows of the Mississippi and Missouri rivers, the Meramec River, and from the alluvial materials bordering these rivers. At the present time, most of the water used in the St. Louis Metropolitan Area is obtained from the Mississippi and Missouri rivers, and these sources should be sufficient to supply any foreseeable increase in demand. Raw water from these surface sources requires a greater degree of treatment than the ground water utilized by cities in the upper basin, but the costs involved are not out of line with the cost of water treatment in most other large metropolitan areas. The supply of water available from the Meramec is small in relation to the supply from the other two rivers, and differences in water quality are

negligible. Because of the costs involved in transporting water, the Meramec is, and will continue to be, the chief source of supply for the southwestern part of the St. Louis Metropolitan Area. At the present time this supply is more than adequate, and will continue to be adequate for some years in the future. Therefore, water supply benefits which might accrue from development of the water resources of the Meramec Basin are likely to be small.

This conclusion does not mean that there will be no direct benefits to municipal and industrial users from development of the water resources of the basin. As the population of this section of the metropolitan area expands, the demand for water from this area will probably exceed the available supply. Benefits would then accrue from making available a larger dependable supply in the Meramec rather than transporting the necessary water from the Mississippi or Missouri. Some additional benefits could also accrue because regulation of streamflow may improve the average quality of surface supplies, which in turn would reduce water treatment costs for municipal and industrial users.

The problems of municipal and industrial water supply in the Meramec Basin and the St. Louis area are small. Consequently, the opportunities for deriving water supply benefits from Meramec water development projects are likewise small. Large expansion of both population and industry is possible without the occurrence of major water problems. Both surface and ground water sources are, and will continue to be, utilized, with the former predominating in the areas outside the Meramec Basin and the latter within the basin.

Introduction

The needs of the Meramec Basin and the St. Louis area for water for municipal and industrial purposes have often been mentioned as a reason for developing the water resources of the Meramec Basin. This report attempts to define these needs more precisely, and to evaluate the adequacy of sources of supply to meet these needs.

The area covered in this report consists of the Meramec River Basin proper and adjacent areas in Metropolitan St. Louis. This area is shown in the frontispiece map. The area outside the Meramec Basin proper includes, roughly, the presently

urbanized portions of the St. Louis Metropolitan Area and those sections which are expected to become urbanized by the year 2000. (At the present time the St. Louis Metropolitan Area includes, in addition to the city of St. Louis, the following counties: St. Louis, St. Charles, and Jefferson in Missouri; Madison and St. Clair in Illinois.)

The nature of the problem can be most easily and clearly presented if it is first divided into its component parts: (a) the water supply and demand of the basin itself, and (b) the water supply and demand in areas bordering the basin. The evaluation of each involves consideration of both surface water and ground water.

The Meramec Basin: Water Supplies

Precipitation and runoff

The ultimate source of water for domestic and industrial uses -- precipitation -- is fairly plentiful in the basin. It varies from 44 inches in the southeast to 40 inches in the northwest, and averages approximately 41 inches annually. Not all of this precipitation becomes surface runoff in the streams of the basin; much of it infiltrates into the ground, evaporates, or is transpired by plants back into the atmosphere. The mean streamflow at the U. S. Geological Survey gage at Eureka (the farthest downstream gage in the basin) is 3110 cfs,[1] which is equivalent to a runoff of only 11.3 inches from the 3788 square mile area drained by the river at that point. In other words, only about one-fourth of the water falling on the basin as precipitation is available as surface water supply in the lower portion of the basin. However, this is not the total amount of precipitation falling in the basin that can be made available to satisfy the water supply needs of the area's inhabitants. An additional amount is available in the form of ground water.

How adequate is the total amount of water available as a result of precipitation in the basin, and how does it compare with the needs or demands for water, both within the basin, and in the immediately surrounding areas which might logically utilize water from the basin? Water is available within the basin from three sources, each of which has differing characteristics. Surface water can be obtained from

streams. Ground water is available from two sources. It can be obtained throughout most of the basin from the soil and rock formations which underlie the basin. Ground water is also available from another source -- the alluvial materials which form the floodplains of the surface streams.

Ground water from bedrock aquifers

Ground water is available from bedrock aquifers throughout the Meramec Basin, but some parts of the basin (notably the northeastern margin) cannot utilize the raw ground water for municipal and industrial purposes. The rock strata which comprise the confined aquifers underlying this part of the Ozarks yield a steady supply of between 150 and 600 gpm (gallons per minute).[2] In the upper basin (roughly that area within the basin boundaries, south and west of a line drawn between Washington and DeSoto), ground water from these aquifers is usable for most purposes with a minimum of treatment, whereas in the lower basin water from these aquifers is relatively highly mineralized and is unusable or undesirable for most purposes without considerable treatment.

Surface water

The magnitude of surface water available is indicated by streamflow measurements at the USGS gaging station, Meramec River near Eureka. Above this point in the lower basin, the drainage area is 3,788 square miles, about 95% of the total drainage area of the Meramec Basin. Based on a 40-year period of record, 1904-1905 and 1922-1959, the average flow at Eureka is 3,110 cfs, or 2,010 mgd (million gallons per day). The minimum recorded flow for the same period is 196 cfs or 127 mgd.[3] Flows in the Meramec during the low flow season are maintained by ground water, particularly the many springs which feed the river and its smaller tributaries.

Dependable supplies of water can be obtained from many of the permanent streams in the basin. The major streams of the basin (those having a drainage area of at least 50 square miles) are shown in the frontispiece map. While drainage area is a good indicator of expected streamflow in many parts of the world, it is not as reliable in the Ozarks because of the many sinks and springs which affect the relationship between drainage area and streamflow. Therefore, not all of the streams shown in

this map will furnish a dependable supply of water, whereas some of the shorter, spring-fed streams not shown on the map could be used as sources of water supply. It is impossible to construct an accurate map of dependable streamflow because of the lack of adequate records covering the numerous streams with small drainage areas which would be necessary for this purpose. The best data available are found in a study of low streamflows done by the U. S. Geological Survey in 1953.[4] A map based on these data is presented as Figure 1. Streamflows at the major gaging stations in the basin during this period were not the lowest ever recorded, but did not, in most cases, exceed the recorded low flow by more than 50%. As shown in Figure 1, the largest amounts of water (more than 100 cfs) are available in the Meramec River downstream from Maramec Spring, near St. James. Amounts on the order of 10-100 cfs are also available from the Meramec for a short distance above Maramec Spring, from the lower portions of the Huzzah, Courtois, and Bourbeuse, and in most of the Big River downstream from the Lead Belt cities.

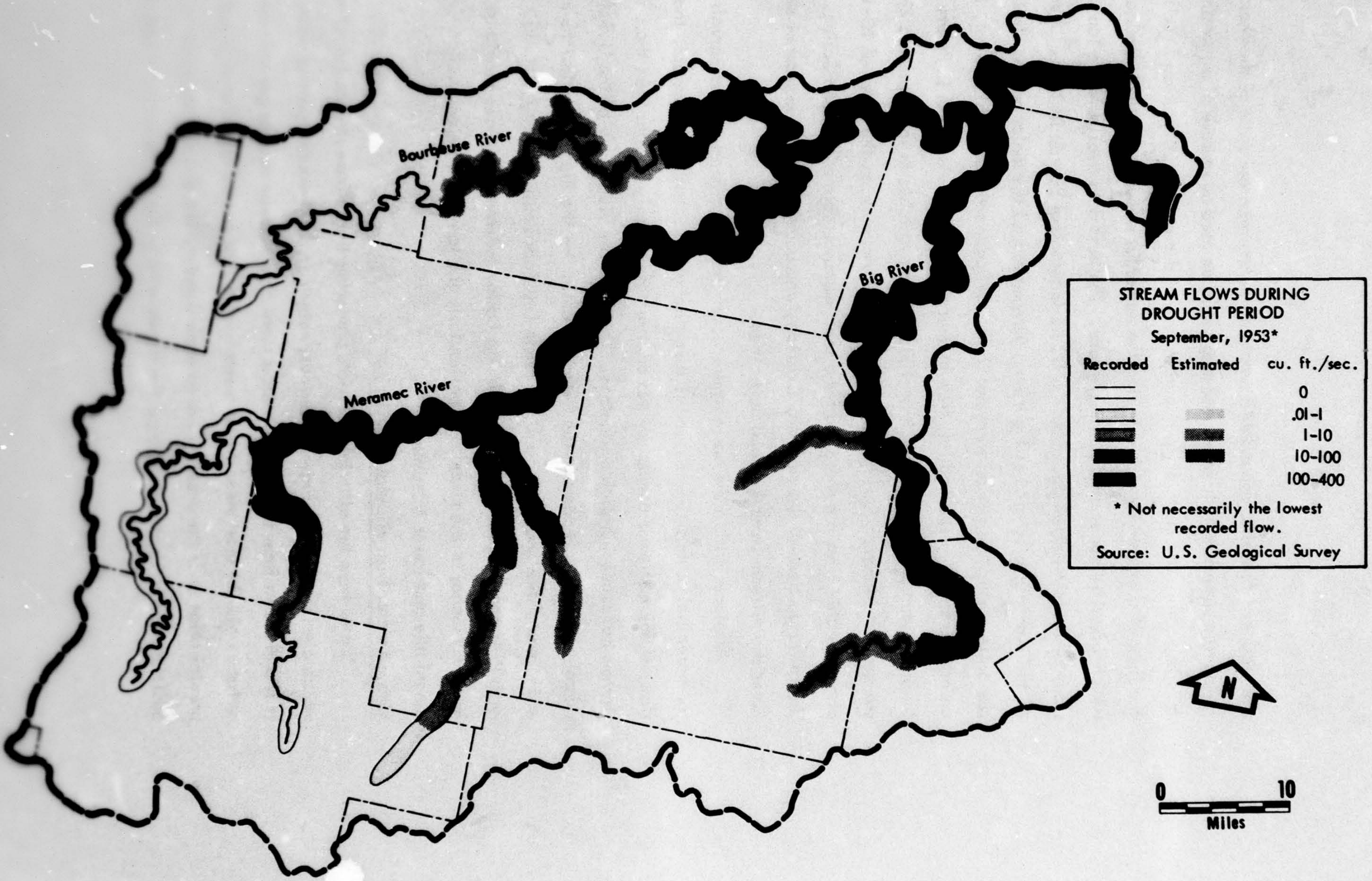
At places within the basin where water from the ground water reservoir is pumped for municipal or mining uses, and is then discharged into surface streams, the base flows of these streams during dry periods are considerably greater than those of similar streams not receiving such discharges. The 1953 low flow study of the U.S.G.S.[5] pinpointed two such areas in the Meramec Basin -- the Big River below the municipalities and mines of the Lead Belt, and the Little Dry Fork below the city of Rolla. If mining activities continue to increase within the basin, extreme low flows should be increased in some reaches of the rivers -- particularly the lower Bourbeuse, Indian Creek, and the middle and lower Meramec.

<u>Ground water from alluvial deposits</u>

Water from the alluvial materials bordering the surface streams has characteristics which are intermediate between surface water and deep-aquifer ground water. Although it is withdrawn from the ground, and is more akin to deep aquifer ground water than surface water by most measures of water quality, its source of recharge is not only precipitation as is the case with deep ground water, but also surface water which infiltrates from the stream. Since the floodplains in the Meramec Basin are seldom

Figure 1

MERAMEC BASIN, LOW STREAMFLOWS



more than one mile wide, alluvial ground water is found only in proximity with surface streams. The pattern of occurrence of alluvial water therefore closely approximates that of surface waters shown in the frontispiece map.

Water supply characteristics

Water from each of these three sources -- surface, deep ground, and alluvial ground -- has differing characteristics which affect its usefulness for domestic and industrial purposes. Usable supplies of deep ground water under present conditions are found in all parts of the basin except the lower portion, while surface and alluvial ground water are available only in stream valleys. With regard to the quantity available, surface water from the major streams provides the largest amount at a single location, followed by alluvial and deep ground water. The three sources can be ranked differently according to various quality criteria: (1) turbidity -- ground water is preferable because of lower turbidity, (2) temperature -- ground water ranks highest because of its relatively constant temperature, (3) hardness -- surface water is preferred because it is generally less hard. Alluvial ground water is intermediate to the other two on the basis of all three of the above criteria, since it is generally comprised of a mix of waters of the other two types.

The quality of the water supply varies from area to area within the basin. Based on the limited data available, hardness of the ground water in the Lead Belt Area (the southeastern portion of the basin) varies between 50 and 650 ppm (parts per million); in the upper basin outside of the Lead Belt Area hardness varies between approximately 100 and 450 ppm.[6] In the lower basin, based on even more limited data, hardness of the ground water is higher than in the upper basin. Where water is withdrawn from alluvial materials adjacent to the Meramec River, its quality varies more throughout the year than ground water in the upper basin, since it is affected by variations in surface water quality. Hardness of these waters has ranged between 270 and 340 ppm. Surface water hardness, based on measurements at two points in the lower basin (Fenton and Kirkwood) ranges between 150 and 200 ppm.[7]

With respect to temperature, ground water varies only a few degrees throughout the year, whereas surface water follows the variations in air temperatures, having a

maximum temperature range of about 45 degrees. Turbidity of alluvial ground water is generally less than 5 ppm in the lower basin and is relatively constant.[8] Average monthly turbidity of surface water in the same area, based on measurements at a single point over a seven year period (1940–1946), varies from about 40 ppm in January, to 170 ppm in June, with an average of about 90 ppm.[9] (Instantaneous turbidity measurements as high as 1,000 to 2,000 ppm have been recorded in the lower Meramec River.) It should be noted that the quantity and quality of surface water are not now affected by any streamflow regulation in the basin.

The Meramec Basin: Municipal and Industrial Water Requirements

Water is used within the basin by municipalities for domestic and other uses including commercial and industrial, by industries directly, and by individual households such as farmsteads or non-farm homes.

Population

The Meramec Basin is not heavily populated -- in fact, parts of it are among the most sparsely populated sections of the eastern United States. About 200,000 to 240,000 persons are now living within the limits of the drainage basin.[10] Those parts of the basin not immediately adjacent to St. Louis (outside the St. Louis Metropolitan Area) account for about 140,000 persons, a density of less than 40 persons per square mile. In this portion of the basin there are only 18 cities which had a population of more than 1,000 at the time of the 1960 census.[11] In the entire basin (including those cities which make up a part of the St. Louis urbanized area) there are 30 cities of more than 1,000 population. These are listed in Table 1.

Rolla, with approximately 11,000 inhabitants, is the only one of the 18 upper basin cities with a population greater than 5,000. (The population of Flat River, when added to that of the cities which make up its contiguous urban area, is almost 10,000.) Seven cities, with some 15,000 inhabitants, comprise the Lead Belt in the southeastern section of the basin. Six cities, comprising about 23,000 inhabitants, are located along an axis running from St. Louis to Rolla. All but Steelville are located on Highway 66 which follows the divide between the Bourbeuse and upper Meramec drainage areas.

Table 1

MERAMEC BASIN CITIES
POPULATION AND WATER SUPPLY CHARACTERISTICS

		Population[a] 1950	Population[a] 1960	Ownership[b]	Source[c]
LOWER BASIN					
(St. Louis Area)	Ballwin	e	5,710	S	S
	Des Peres[d]	1,172	4,362	S	S
	Ellisville	628	2,732	S	S
	Eureka	e	1,134	M	G
	Kirkwood[d]	18,640	29,421	M & S	S & A
	Manchester	e	2,021	S	S
	Pacific	1,985	2,795	M	G
	Sunset Hills[d]	e	3,525	S	S
	Town & Country[d]	162	1,440	S	S
	Valley Park	2,956	3,452	M	A
	Winchester	176	1,299	S	S
	Fenton	207	1,059	S	S
UPPER BASIN					
Lead Belt	Bismark	1,244	1,237	L	G
	Bonne Terre	3,533	3,219	L	G
	Desloge	1,957	2,308	L	G
	Elvins	1,977	1,818	L	G
	Esther	e	1,033	L	G
	Flat River	5,308	4,515	L	G
	Leadwood	1,479	1,343	L	G
Highway 66 Axis					
(St. Louis to Rolla)	Rolla[d]	9,354	11,132	M	G
	St. James	1,996	2,384	M	G
	Cuba	1,301	1,672	M	G
	Sullivan	3,019	4,098	M	G
	St. Clair	1,779	2,711	M	G
	Steelville	1,157	1,127	M	G
Highway 50 & 28 Axis					
(Missouri-Bourbeuse Divide)	Union	2,917	3,937	M	S
	Owensville[d]	1,946	2,379	M	G
	Belle[d]	906	1,016	M	G
Other	Potosi	2,359	2,805	M	G
	Salem	3,611	3,870	M	G
	Viburnum	53	590	?	G

[a] From U.S. Bureau of Census, U.S. Census of Population, 1960.

[b] OWNERSHIP
- S - St. Louis County Water Co.
- L - Lead Belt Water Co.
- M - Municipal

[c] SOURCE OF SUPPLY
- S - surface water
- G - ground water from bedrock aquifers
- A - ground water from alluvial aquifers

[d] Located partly outside the Basin.

[e] Unincorporated area with less than 1,000 population in 1950.

Three cities in the 1,000+ category, along with several smaller ones, are located along the Bourbeuse-Missouri River divide. Rounding out the list are Salem in the southwestern part of the basin, and Potosi, some 15 miles west of the Lead Belt cities.[12]

Municipal water demands

All of the lower basin cities which are contiguous parts of the St. Louis urbanized area obtain their water from surface or alluvial sources. The other two lower basin cities, Eureka and Pacific, depend upon ground water from bedrock aquifers. These two cities, along with Valley Park and Kirkwood, have their own municipal water systems; the others are supplied by the St. Louis County Water Company, a private corporation. The St. Louis County Water Company obtains some of its total water withdrawals directly from the Meramec River; most of its supply from the Missouri River. The city of Kirkwood obtains the major portion of its supply from a radial-type well running beneath the bed of the Meramec River. Kirkwood also has a direct surface water intake which can be used to supplement the well yield when necessary. (In addition Kirkwood currently purchases about one-eighth of its needs from the St. Louis County Water Company.) The city of Valley Park obtains its total supply from shallow wells near the Meramec River.

In the upper basin only one city, Union, obtains its water from a surface source, the Bourbeuse River. The municipal requirements of the other cities are met from ground water. Outside of the Lead Belt, all of the upper basin cities are served by municipally-owned systems. The Lead Belt cities utilize ground water pumped from the mines and sold by the Lead Belt Water Company, a subsidiary of St. Joseph Lead Company.

Most of these agencies encounter little difficulty in obtaining all water needed for municipal and industrial purposes. In fact there appear to be adequate supplies for any anticipated population and industrial expansion in the basin. Possible exceptions to the above generalization are Rolla and St. Clair in the upper basin. Rolla, in the headwaters, has eight wells in operation at present. Indications suggest there may be difficulty in finding locations for enough additional wells to supply the growing

needs of the Rolla area. St. Clair is likewise encountering difficulty in meeting its needs from local ground water supplies, due probably to the decreased thickness of the Potosi formation in that area. In both cases however, the potential maximum economic yields from the relevant ground water basins are not known as yet, but it is reasonably certain that with proper spacing of well fields, sufficient quantities of ground water should be obtainable to satisfy the present and future needs of these two cities, as well as the needs of the other cities in the upper basin.

Figure 2 shows the location of surface-water-using municipalities compared with the pattern of sub-surface water availability in the United States. Within the zone of ground water availability, practically no municipalities except large cities (in the 100,000+ class) make use of surface water supplies. In most parts of the Meramec Basin, the quantity of water available from underground sources is even larger than the minimum specified on Figure 2.

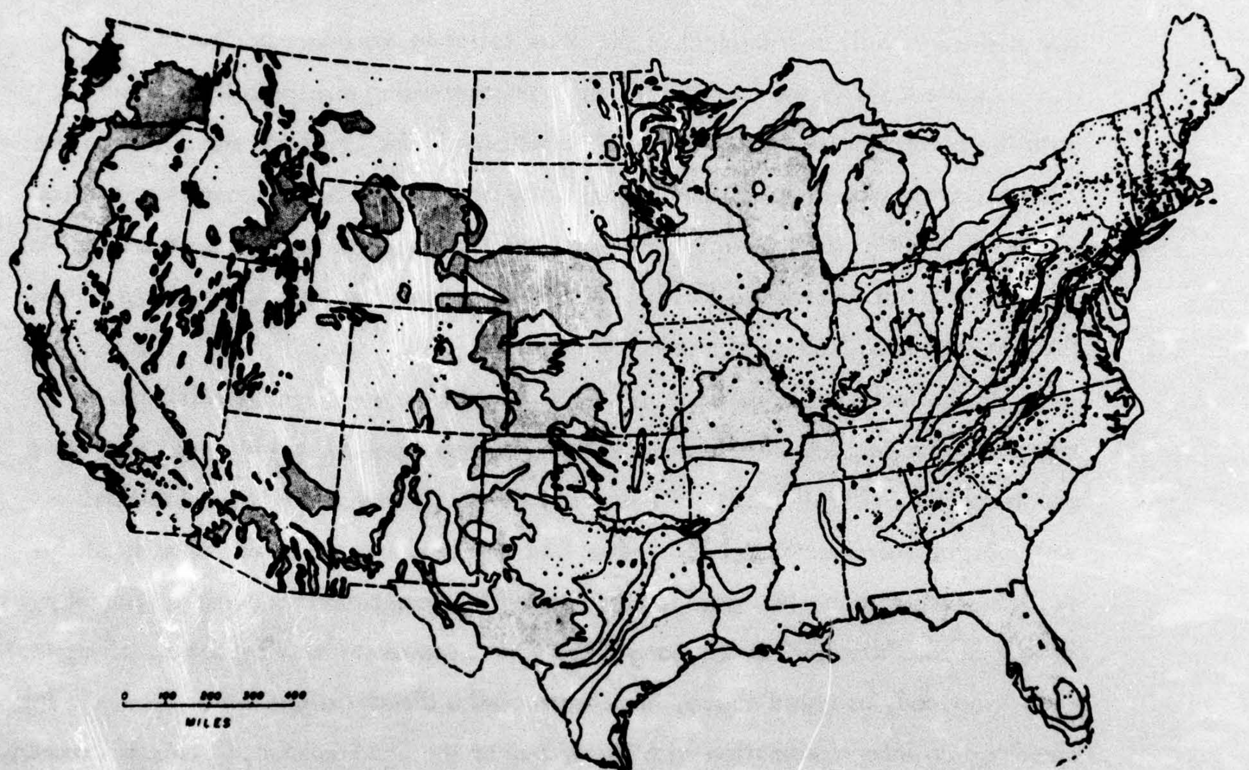
In the lower basin only the city of Kirkwood has experienced difficulty in meeting water requirements in recent years, during a period in which demands have grown rapidly. The difficulty however did not result from a shortage of available water in the Meramec River, but rather from the inadequate intake capacity of the shallow wells tapping the supply, plus limited treatment plant capacity. Thus the impact of the "drought" in the early 1950's has been over-rated by some. Since that time Kirkwood, as noted above, has constructed a direct surface water intake in the river and an inter-connection with the system of the St. Louis County Water Company. These sources are available to supplement the well yield when necessary.[13]

Industrial water demands

While there is some present requirement for water for industrial uses in the basin proper, it is of limited magnitude. Most of the manufacturing industries presently located in the basin have relatively modest water requirements which are generally supplied by municipal water systems. No heavy water-using industries such as oil refining, steel manufacturing, pulp and paper manufacturing or steam power plants, are located within the basin.[14] Mining is the major industrial water-user, the water requirements for which are met from ground water and supplied by the mining

Figure 2

THE PATTERN OF SURFACE-WATER-USING MUNICIPALITIES IN THE UNITED STATES COMPARED WITH THE PATTERN OF SUB-SURFACE WATER AVAILABILITY



Dots indicate location of surface-water-using municipalities. Shading indicates areas where ground water is available in quantities adequate to constitute a supply of fresh water for a town of about 1,000 inhabitants (water containing less than 2,000 parts per million of disolved solids at rates exceeding approximately 72,000 gallons per day). In most of the Meramec Basin, even larger amounts of ground water are available.

Source: John R. Borchert, "The Surface Water Supply of American Municipalities. Annals of the Association of American Geographers, Volume 44 (1954). Reproduced through the courtesy of the author.

companies' own systems. Sand and gravel operations are also important in the basin, but, as with mining, most of the water withdrawn is returned to streams or ground water basins in the area from which it is withdrawn. Water quality degradation is the major problem with respect to both mining and sand and gravel operations. However, with the exception of a few sand and gravel operations, the situation appears to be under control. Considerable growth in mining operations is expected in the basin over the next 40 years. All indications are that the water requirements for industry and mining can be met by development of local ground and surface water.

Water demands of individual households

Water for the use of individual households is supplied by ground water generally from shallow wells tapping unconfined, non-alluvial aquifers. In the upper basin little difficulty is experienced in obtaining enough water by this means. Even under drought conditions, only the very shallow wells are affected. Under normal economic conditions, farmers should be able to "afford to tap aquifers of a depth necessary to insure a year around supply despite droughts."[15] Stock-watering needs are met from wells, farm ponds, surface streams, or some combination of these sources.

In the lower basin, where density of dwelling units is generally higher and the deep ground water is more highly mineralized, individual households are already experiencing difficulties in obtaining water. These difficulties are expected to increase with increasing population. Pollution of the shallow aquifers has been added to the problems of quantity and mineral quality in parts of this area.

Estimates of the population living within the various political subdivisions of the Meramec Basin in 1960 are given in Table 2.[16] Column 1 shows the estimated 1960 population; column 2, the median projected population for the year 2000, based on past trends and other factors (particularly proximity to St. Louis and the advent of new mining); columns 3 and 4 show the estimated annual water requirements for the year 2000 based upon the population estimates contained in column 2. According to Thomas R. Beveridge, Missouri State Geologist, these requirements could be met, without difficulty, from proper development of ground water resources -- with the exception of the requirements of Jefferson County (particularly the northern portion)

Table 2

MERAMEC BASIN COUNTIES AND MAJOR TOWNS
ESTIMATED POPULATION AND WATER DEMAND

COUNTY & TOWN	POPULATION[a]		WATER DEMAND	
	1960	Estimated 2000	Acre-Feet	Million Gallons Per Day
Crawford	12.5	25	5,000	3.5
Bourbon	.8	3	600	.42
Cuba	1.7	5	1,000	.7
Steelville	1.1	5	1,000	.7
Dent	9.0	12	2,400	1.68
Salem	3.9	10	2,000	1.4
Franklin	26.0	75	15,000	10.5
Sullivan (also Crawford Co.)	4.1	20	4,000	2.8
St. Clair	2.7	10	2,000	1.4
Pacific-Grey Summit	2.8[b]	10	2,000	1.4
Union[c]	3.9	15	3,000	2.1
Gasconade	2.5	3	1,500	.42
Owensville (partly outside Basin)	2.4	5	1,000	.7
Iron	1.5	5	1,000	.7
Viburnum	.6	3	6,600	.42
Jefferson[d]	28	200-300	50,000	35
Northern Part		200	40,000	28
Hillsboro (partly outside Basin)	.5	15	3,000	2.1
Cedar Hill		15	3,000	2.1
Maries	2	2	400	.28
Phelps	20	35	7,000	4.9
Rolla (partly outside Basin)	11.1	20	4,000	2.8
St. James	2.4	5	1,000	.7
Reynolds	.1	-------	negligible	-------
St. Francois	25	25	5,000	3.5
Flat River-Bonne Terre and suburbs	7.7[e]	25	5,000	3.5
St. Louis County[d]	60-80	200-300	50,000	35
Washington	14.1	20	4,000	2.8
Potosi	2.8	5	1,000	.7

[a] 1960 population of towns for city limits only, generally 30-60% less than actual built-up area, from U.S. Census of Population, 1960. Population estimates for 2000 cover whole built-up area. Estimates are median projection, adjusted for proximity to St. Louis and advent of new mining.

[b] Pacific only.

[c] The City of Union and portions of St. Louis County are presently supplied by surface water. All others rely on ground water.

[d] The whole of northern Jefferson County is estimated to have suburban or semi-suburban density by 2000 as far as Hillsboro and Cedar Hill. All of St. Louis Co. to have suburban density by 2000.

[e] Flat River and Bonne Terre only.

and St. Louis County. The characteristics of the ground water of this area are described on the map, Missouri Water Resources,[17] as "Limited yields of fresh water at depths up to 500 feet. Salty or sulphurous water at greater depths dependent upon location." When the population density of this area has increased so as to approach that of present-day suburban areas, the residents will be forced to depend upon surface water supplies to meet the demand (barring unexpected breakthroughs in the costs of demineralizing brackish waters). This demand could be met by expansion of the territory served by the St. Louis County Water Company, or by the formation of one or more public or private companies to distribute waters taken from the Meramec Basin or the Mississippi-Missouri system. These problems are treated in more detail in the section describing St. Louis area water needs.

Possible water supply benefits from major impoundments

Water supply is not a major problem anywhere in the Meramec Basin at the present time. It is extremely unlikely that changes taking place within the next 40 years will produce any large-scale water supply problems in the upper basin. During this period changes in the lower basin, caused by the further expansion of the St. Louis urbanized area into this section, will probably result in some problems.

Water-supply benefits to be derived from the construction of reservoirs on the major streams in the Meramec Basin appear to be extremely limited for the upper basin -- perhaps nonexistent. So long as ground water continues to yield an adequate supply there seems to be little reason for utilizing waters directly or indirectly from any impoundments, considering the distance over which this water would have to be transported. Steelville, Union, and the Lead Belt cities are the only sizeable cities in the upper basin located within two miles of major streams.[18] If ground water should prove inadequate in some places consideration should be given to, and costs evaluated for, alternatives other than main-stem reservoirs. The cheapest alternative might prove to be construction of smaller near-by reservoirs, solely or primarily for water supply, or construction of a pipeline to a surface water source outside the basin. For example, the distance from Union to the Missouri River and from Rolla to the

Gasconade River is less than ten miles. While such distances may be beyond the realm of economic feasibility for these towns, the fact remains that they compare favorably to the distances involved in directly tapping potential main-stem reservoirs.

Ground water quality in the upper basin is sufficiently high for most purposes. Only a minimum of treatment is required -- in most municipalities treatment is limited to chlorination and softening. The major water quality problems stem from hardness.

Improvement in this last mentioned aspect of water quality, hardness, has been suggested as a possible source of benefit in the upper basin. As noted previously, ground water hardness varies between 100 and 650 parts per million in the upper basin (practically all areas outside the Lead Belt average less than 300 ppm). Surface water hardness in the basin has been measured systematically at only two places -- both in the lower basin. On the basis of these records (1940-1946) surface water hardness appears to vary between 60 and 280 parts per million and averages 185 parts per million at the Kirkwood water plant. Hardness can be reduced by impoundment in two ways: (1) dilution by peak discharges which have generally lower hardness, and (2) photosynthetic carbonate precipitation.[19] The first would probably result in a reduction in average hardness from 185 to about 175 ppm. The effect of the second is more difficult to evaluate because of limited data -- however, based on experience at reservoirs on the Missouri River, a further reduction of 5-10 ppm (to 165-170 ppm) seems to be approximately the magnitude of change which could be expected.[20] The hardness of water withdrawn from a Meramec reservoir, therefore, would probably be in the 150-175 ppm range. A comparison with ground water having a hardness of about 300 ppm indicates that the substitution of reservoir water for ground water might well mean a reduction in the hardness on the order of 100-200 ppm of raw water available to municipalities. Whether the ensuing reduction in the costs of treating water for hardness would be sufficient to balance the increase in other treatment costs and transmission costs is a question which would require further study. However, at the present time, persons most familiar with the municipal water supply situation in this area do not feel that any savings in municipal water costs are likely to be realized as a result of reservoir construction.

Considering the available alternatives, the expense of transporting water by pipeline for even a few miles becomes a limiting factor to utilizing water directly from multi-purpose reservoirs. If, however, the stream channel itself can be used as a natural aqueduct to transport the water from reservoirs to the point of demand, transportation costs would be non-existent. Two upper basin cities, Union and St. Clair, along with all of the listed lower basin cities might be physically in a position to benefit from such increases in the dependable supply of water available from the river. However, in order for there to be any economic benefit to these two cities from such increases, it would be necessary to show that existing actual or potential sources of supply are inadequate. Such is not the case. At Union, the lowest streamflow recorded during the period of record (1921 to 1958) is 11 cfs (7 mgd). This is well in excess of the average daily withdrawals of the city of Union in 1958 -- 0.44 cfs (0.28 mgd). It is difficult to imagine a serious water shortage arising at Union. Mention has been made previously of the difficulty encountered by the city of St. Clair in obtaining sufficient quantities of ground water to meet its requirements. If this problem should prove insurmountable, as appears most unlikely, it might prove feasible to look to surface sources. In the nearest major stream, the Meramec, minimum flows are in excess of 131 cfs (84 mgd).[21] St. Clair's present withdrawals are less than 0.1 mgd. There is absolutely no need to increase the minimum quantities of surface water available to St. Clair.

In the lower basin the present withdrawals from the Meramec River for municipal and industrial uses (exclusive of sand and gravel operations) probably total around 25 mgd on the maximum day. This represents about 20% of the minimum recorded daily flow of the Meramec at Eureka. Thus it is obvious that considerable potential exists for expansion of withdrawals from the river and from the adjacent alluvial materials recharged by the river, even without regulation of streamflows.[22] What regulation might well accomplish however, would be an improvement in the average quality of the water with a corresponding reduction in treatment costs for the municipal and industrial users.

The St. Louis Area: Water Supplies

The water supply picture in the St. Louis area differs substantially from that within the Meramec Basin. The area under consideration (primarily the St. Louis urbanized area) is considerably smaller, and more uniformly built up -- resulting in less variation of both supply and demand from place to place within this area. (For example; there are no sizeable areas of practically zero demand such as exist in the Meramec Basin, and no areas more than ten miles removed from a large source of surface water.)

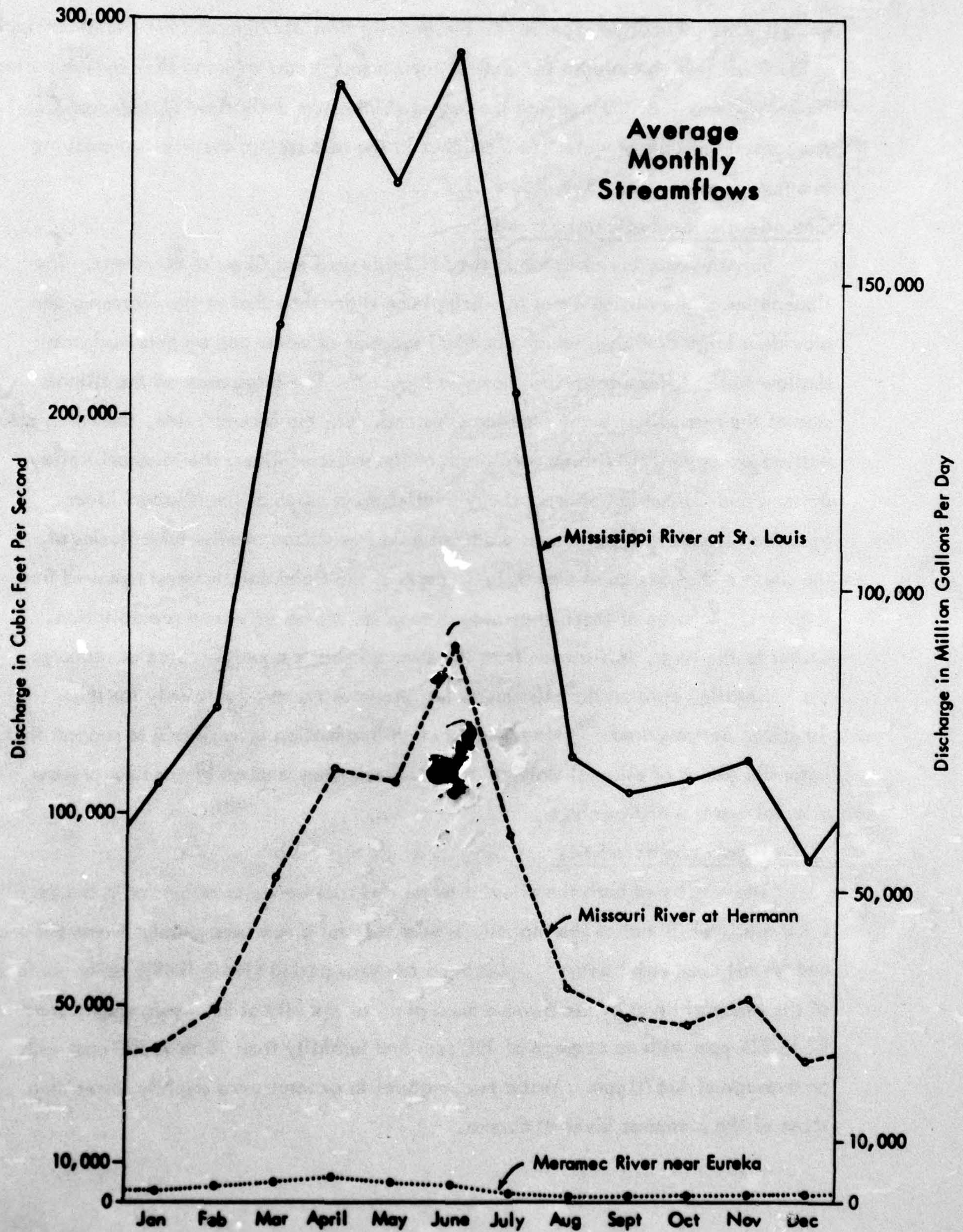
Ground water from bedrock aquifers

No part of the St. Louis area is as well off as most parts of the Meramec Basin with regard to supplies of ground water from bedrock formations. The yield from deep aquifers in this region is generally lower, and the quality almost invariably poorer, as one proceeds from the older strata of the central part of the Ozark Dome toward the younger strata to the north and east. Ground water from these aquifers in the St. Louis area is too highly mineralized for most uses. At the present time its primary use is in some swimming pools and health clubs. Ground water yields from shallow bedrock formations or from unconsolidated wind-blown soil deposits (loess) are usable by isolated households or establishments but are not sufficient to meet the demands of even moderately intense urban development. Pollution of these shallow aquifers from septic tanks is tending to reduce further the already limited usefulness of this source of supply. Ground water from non-alluvial sources is not now an important source of water in the St. Louis area, and does not appear likely to gain in importance.

Surface water

The St. Louis area is particularly well situated with regard to supplies of surface water. The flow of the Mississippi River at St. Louis represents the combined drainage of the Missouri-Upper Mississippi System -- an area of approximately 700,000 square miles. The Missouri River is utilized especially to supply the needs of St. Louis County. The Mississippi below its confluence with the Missouri is the primary source of supply for the cities and industries of St. Louis and its Illinois suburbs. The average daily flow of the Missouri River at Hermann, Missouri for the period 1898-1958[23]

Figure 3


Average
Monthly
Streamflows
Discharge in Cubic Feet Per Second
Discharge in Million Gallons Per Day
300,000
200,000
100,000
50,000
10,000
0
150,000
100,000
50,000
10,000
0
Mississippi River at St. Louis
Missouri River at Hermann
Meramec River near Eureka
Jan
Feb
Mar
April
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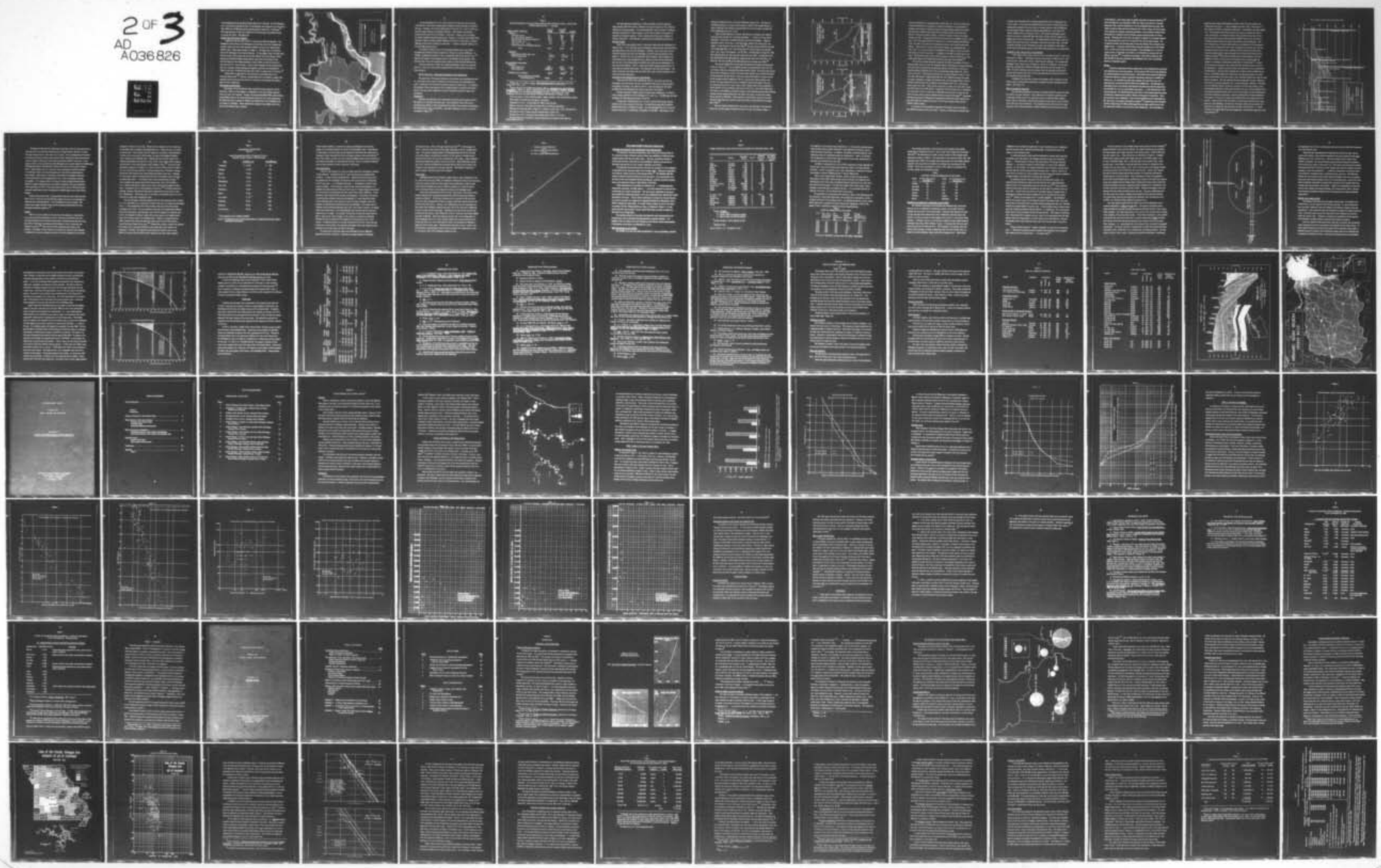


was 51,600 mgd and the recorded minimum daily flow 2,720 mgd. For the Mississippi at St. Louis (which includes the flow of the Missouri), the average flow for the period 1861-1958 was 113,000 mgd and the recorded minimum daily flow 11,600 mgd.[24] The largest amounts of water are available in the late spring; the smallest amounts in autumn and winter. (See Figure 3).

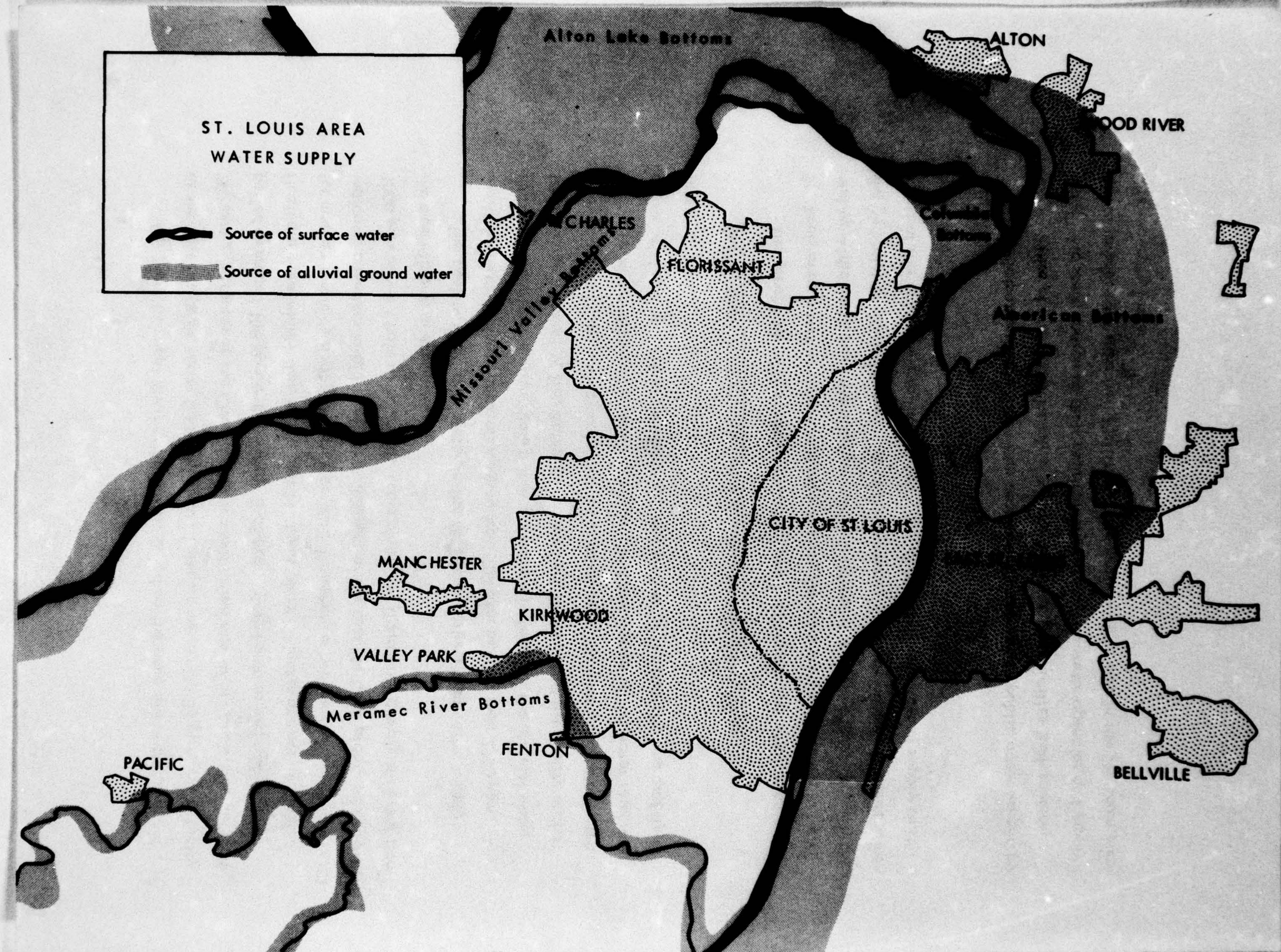
<u>Ground water from alluvial deposits</u>

Supplies of alluvial water in the St. Louis area are likewise abundant. The floodplains of the Missouri and Mississippi are wider than that of the Meramec and provide a large area over which abundant supplies of water can be obtained from shallow wells. These areas are shown in Figure 4. The large area on the Illinois side of the Mississippi is the American Bottoms. On the Missouri side, the Alton Lake Bottoms occupy a fairly large area north of the Missouri River; the Missouri Valley Bottoms and Columbia Bottoms occupy smaller areas south of the Missouri River (and the Meramec River Bottoms produces a narrow ribbon of alluvial material at the south end of St. Louis County). In parts of the floodplain farthest removed from the river, recharge of these underground supplies is primarily from precipitation. Closer to the river, infiltration from the stream itself is a major source of recharge.[25]

Detailed data on the alluvial water resources are available only for the American Bottoms area.[26] However, enough infomation is available to suggest that potential yields of alluvial water in the St. Louis area is much larger than present alluvial water withdrawals.

<u>Water supply characteristics</u>

The quality of both the alluvial water and surface water resources in the St. Louis area, while not of the highest, is adequate for a few uses without treatment and for all uses with treatment. During a ten year period (1940-1949), daily hardness of the Missouri River at the Howard Bend plant of the city of St. Louis ranged from 82 to 326 ppm with an average of 190 ppm and turbidity from 18 to 9,300 ppm with an average of 1,670 ppm. Water temperatures in general were slightly lower than those of the Meramec River at Eureka.


ST. LOUIS AREA
WATER SUPPLY
Source of surface water
Source of alluvial ground water
Alton Lake Bottoms
ALTON
OOD RIVER
CHARLES
Missouri Valley Bottoms
FLORISSANT
American Bottoms
CITY OF ST LOUIS
MANCHESTER
KIRKWOOD
VALLEY PARK
Meramec River Bottoms
FENTON
PACIFIC
BELLVILLE

For the Mississippi River at St. Louis, based on the same ten years of record at the East St. Louis Water Company plant, hardness averaged 183 ppm and turbidity 292 ppm. Hardness at the Chain of Rocks plant of the city of St. Louis, for the same period averaged 188 ppm and turbidity 1,325 ppm. Both hardness and turbidity fluctuate more widely than at the East St. Louis plant. Figures are not available for median turbidity during the same period. However, a two-year record (1949-1950) indicates a median turbidity of about 300 ppm at the East St. Louis plant, and about 1,000 ppm at the Chain of Rocks-St. Louis plant -- figures not greatly different from the mean figures given above.

The quality of alluvial water in the American Bottoms area varies widely. Available data indicate hardness ranging from 157 ppm to more than 2,980 ppm. In addition, troublesome quantities of iron are generally found in the alluvial water.[27] Data for the Missouri Valley Bottoms area are very limited, but the quality of the alluvial water in the area probably varies as much as in the American Bottoms area.

The above discussion, while not a detailed description of the water resources of the St. Louis area, does provide a general picture of the quantity and quality of these resources.

The St. Louis Area: Municipal and Industrial Water Requirements

The great bulk of the present industrial and municipal water requirements in the St. Louis area is met by direct withdrawals from the Missouri and Mississippi rivers and by withdrawals from the alluvial materials adjacent to those rivers. In analyzing the potential of the water resources of the Meramec Basin for meeting future requirements of this area, the availability and costs of alternative sources of supply must be assessed.

Withdrawals

Municipal and industrial water requirements are met by public agencies and by the facilities of individual industrial users. Some industries utilize both sources, purchasing some portion of their requirements from public water agencies and supplying the remainder from their own facilities. The major withdrawals in the St. Louis area are shown in Table 3.[28]

Table 3

MAJOR INDUSTRIAL AND MUNICIPAL WATER WITHDRAWALS IN THE ST. LOUIS AREA
(Million gallons per day -- average)

	Searcy[a] (1950)	Bi-State[b] (1954)	(1960[c])
PUBLIC WATER AGENCIES			
SURFACE			
City of St. Louis	157	150	180[d]
St. Louis County Water Co.	27.2	22[e]	67[d]
East St. Louis & Interurban Water Co.	29.5	29	30
City of Alton, Ill.	6.7	6.8	7
City of St. Charles, Mo.	1.3	1.2	1
Other Illinois (non-Mississippi sources)		1.1	1
Total	221.7	210.1	273
GROUND			
Kirkwood and Valley Park, Mo.	1.4	1.9	2
Illinois Communities	4.3[7][f]	3.1[12][f]	4
Total	5.7	5.0	6
SELF-SUPPLIED INDUSTRIAL			
SURFACE			
Union Electric Co.	950[g]	940[h]	1,200[i]
Other industrial	20-27[4][f]	45[3][f]	50
GROUND (all in Illinois)	28[2][f]	80[33][fj]	90
Total Industrial not including Union Electric Co.	48-55	125	140

[a]Taken from J. K. Searcy, *et al.*, *Water Resources of the St. Louis Area*, U.S.G.S. Circular No. 216, p. 52.

[b]Taken primarily from Bi-State Development Agency, *Mississippi River Water Pollution Investigation*, (1954), pp. 28-32. Supplemented by data from Elmer P. Lotshaw, *The Role of Water Resources in the Industrial Development of the St. Louis Region* (St. Louis: Washington University Graduate School of Business Administration, no date), p. 33.

[c]Our own estimates unless otherwise stated. Figures rounded to the nearest million gallons.

[d]Data obtained directly from the agency concerned.

[e]Apparently an error. Correct figure for 1954 is about 43 mgd.

[f]Figure in brackets is the number of communities or industries represented.

[g]Includes the following plants: Ashley St., Cahokia, Venice Nos. 1 & 2, and Mound St.

[h]Includes the plants in item g plus the Meramec Plant, Units 1 & 2.

[i]Includes the plants in item g plus the Meramec Plant, Units 1, 2, 3, & 4.

[j]Of these thirty-three industries, nineteen each pump an average of more than one million gallons per day.

The total estimated withdrawals in 1960 are slightly more than 1600 mgd. Approximately 75% of this total is withdrawn by the several plants of Union Electric Company for cooling purposes. Of the remaining 25%, about one-third is withdrawn directly by industries for various purposes, and the rest by public water systems for domestic and industrial purposes. Only a small portion of the water withdrawn is actually "consumed". The remainder is returned to the Mississippi River after use.

Sources of supply

Most of the water supply of the St. Louis area is taken from the Mississippi and Missouri rivers. All of the water used for condenser cooling of steam-powered electric generating plants comes from the Mississippi. Similarly, most of the water used for industrial purposes comes from the Mississippi or from the alluvial materials which border it. The East St. Louis and Interurban Water Company, which supplies much of the Illinois part of the metropolitan area, obtains its water from the Mississippi. The city of St. Louis obtains about two-thirds of its water from the Mississippi, and the rest from the Missouri. The St. Louis County Water Company obtains most of its water from two Missouri River plants. The remainder comes from the Meramec. The cities of Kirkwood and Valley Park also obtain their water from the Meramec or the alluvial materials bordering it.

Capability of the Mississippi River to meet demands

Since more than 90% of the withdrawals in the St. Louis area are from the Mississippi, and since most of the area not supplied by this source is near enough to be supplied if necessary, the relation of the St. Louis area demand to the supply available from the Mississippi River will be examined in more detail.

The data contained in Table 3 reflect average water withdrawals. In relation to the average streamflow of the Mississippi at St. Louis, i.e., 113,000 mgd, the total withdrawal in 1960 represents between 1% and 2%.

Average daily withdrawals do not, of course, indicate the maximum demand placed on the water resources of the river. Nor does the average daily streamflow indicate the minimum conditions of supply. For the Mississippi River at St. Louis the minimum daily flow is 11,600 mgd, on December 21-23, 1863. With respect to this

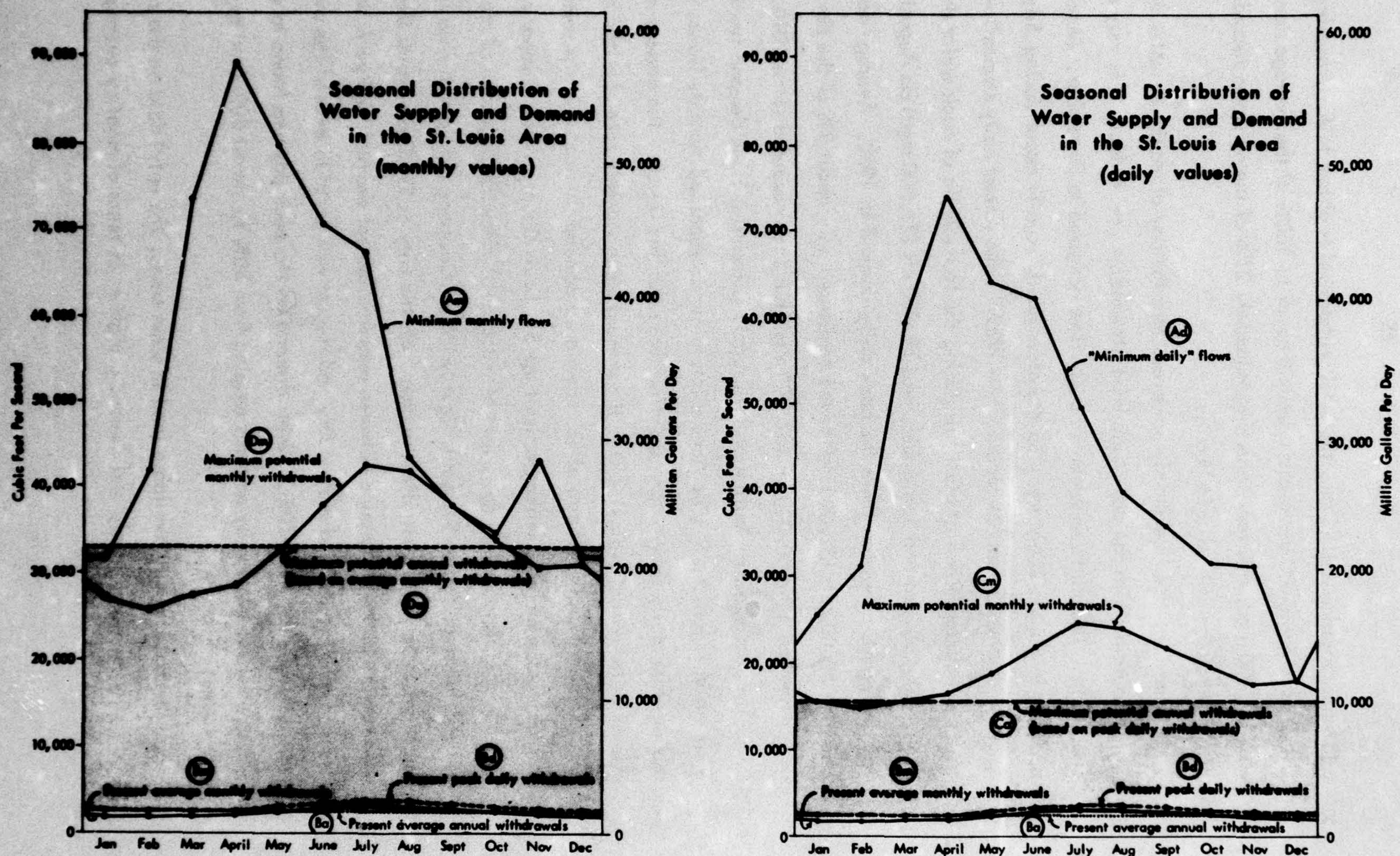
minimum recorded daily flow, the total withdrawal is about 14%. Assuming, for illustrative purposes, a maximum demand equal to 150% of the average demand, or about 2,430 mgd, this represents approximately 21% of the minimum recorded flow of the Mississippi River at St. Louis.

There is little likelihood, however, that the day of maximum water demand would coincide with the day of minimum streamflow -- in fact, it is very nearly impossible. The minimum recorded daily flow occurred in December. Maximum demands in the St. Louis area, on the other hand, usually occur during July and August. In the 25 years of record since 1933,[29] the lowest daily streamflow recorded on the Mississippi River at St. Louis during the four months of peak water demand, June, July, August and September, was 39,700 cfs (25,600 mgd) on August 28, 1936. This represents about ten times the peak daily demand in 1960. Average daily flows less than 50,000 cfs (32,000 mgd) were registered only about 2% of the time. No daily flow less than 50,000 cfs (32,000 mgd) has been recorded since 1940.[30]

The seasonal distribution of both supply (streamflow) and demand (withdrawals) is shown in Figure 5.[31] Line Am depicts minimum recorded monthly flows; line Ad, the minimum daily flow recorded during those months; line Ba, the present mean annual rate of water withdrawal; line Bm, the present mean monthly rate of withdrawal based on the assumption that the total St. Louis area demand fluctuates in the same manner as the average monthly withdrawals of the St. Louis County Water Company; and line Bd, the present peak daily rate of withdrawal allowing the shape of the curve to be determined by the St. Louis County Water Company data and the amplitude of the fluctuation to be controlled by data from the City of St. Louis Water Department with respect to the difference between average annual demands and peak daily demands. Average monthly demand during July and August was found to exceed the average annual demand by 25%-30%. Water demand on the peak day was found to exceed average annual demand by amounts ranging from 30% to almost 60% (and averaging about 40%).[32]

The most readily available (and in some cases, the only) data on the seasonal fluctuation of water supply and demand are given in terms of monthly averages --

Figure 5


Seasonal Distribution of Water Supply and Demand in the St. Louis Area (monthly values)
Minimum monthly flows
Maximum potential monthly withdrawals
Present average annual withdrawals
Cubic Feet Per Second
Million Gallons Per Day
Jan
Feb
Mar
April
May
June
July
Aug
Sept
Oct
Nov
Dec
Seasonal Distribution of Water Supply and Demand in the St. Louis Area (daily values)
"Minimum daily" flows
Maximum potential monthly withdrawals
Present average monthly withdrawals
Present peak daily withdrawals
Present average annual withdrawals

minimum monthly flows, average monthly withdrawals, etc. The use of these data would be satisfactory for comparison of supply and demand if it were possible to average out variations in supply by means of storage facilities sufficient to handle the increment of demand over supply for those periods during which short-term demand is above the monthly average, or short-term supply is below the monthly average (or both). Storage facilities of this size are not now available in the St. Louis area. The water storage facilities of the city of St. Louis (including both filtered water and water in the process of treatment) are equal to two times the peak daily demand. Those of the St. Louis County Water Company are considerably less. In other words, the critical period for consideration of the supply of water is less than one month, but more than one day -- probably on the order of several days to one week. This should be kept in mind in this discussion in which monthly and, in some cases, daily figures were used because these were the only ones available.[33]

On the basis of these estimates of seasonal fluctuation of demand, the total demand which can be met with the available supply in the absence of storage facilities can be derived by graphically increasing the demand until some part of the curve depicting demand intercepts part of the curve depicting supply (Figure 5). This is shown in line Dm. When the mean annual rate of water withdrawal in the St. Louis area (line Da) reaches 21,000 mgd (32,500 cfs), the withdrawals during the months of August, September, October and December will coincide approximately with the minimum mean monthly flow recorded for the Mississippi River at St. Louis during those months since 1861. Other months would have a surplus over needs which range from 20% (January) to 200% (April). Comparison with the present rate of withdrawals for all purposes in the St. Louis area (1,620 mgd) shows demand to be less than 8% of the maximum which could be satisfied without storage (21,000 mgd).[34] Comparison with the present rate of withdrawals by organizations other than Union Electric Company (340 mgd) shows demand to be about 1.6% of the maximum which could be satisfied without storage.

An analysis of water demands as compared with minimum daily flows (Ad) is more difficult because of the lack of data. However, on the basis of available data,

it appears that December (with a minimum recorded daily flow 11,600 mgd) is the critical month. Since peak daily demand (Cm) in that month is slightly above the average daily demand for the year (Ca), an average demand of about 10,000 mgd can be handled without storage and without undue difficulty. (See Figure 5.) Present withdrawals for all purposes in the St. Louis area (1,620 mgd) are about 16% of this amount; withdrawals other than those of Union Electric Company are slightly more than 3% of this amount. For reasons pointed out previously, the most logical time period to consider is less than a month but more than a day. The most reasonable estimate of the relationship of present total demands to total supply is on the order of 8% (monthly data) to 16% (daily data) depending on the period used.

Capability of the Missouri River to meet demands

With respect to the Missouri River as a source of supply for the St. Louis area the situation is similar. Withdrawals from the Missouri River in 1960 in the St. Louis area and in St. Charles and vicinity, totaled less than 100 mgd. The average daily discharge of the Missouri River at Hermann, Missouri is 51,600 mgd. The minimum daily flow recorded since 1928 is 2,720 mgd, the latter occurring January 10-12, 1940. The total withdrawals from the Missouri River for municipal and industrial purposes then represent less than 1% of the average daily flow and less than 4% of the recorded minimum daily flow.

Additional flows from the Meramec are available and are utilized, but they make up only a small portion of the amount available from the Mississippi-Missouri system. (See Figure 3.)

Effect of streamflow regulation

The preceding comparisons are based on existing streamflow records and therefore reflect only past conditions. The construction of streamflow regulating works on the upper reaches of this river system can result in a changed stream regimen. Such a system of regulating works has been proposed for the Missouri, and is already well on the way toward completion. The completed system will consist of six major reservoirs with a combined capacity of about 75 million acre-feet on the main stem

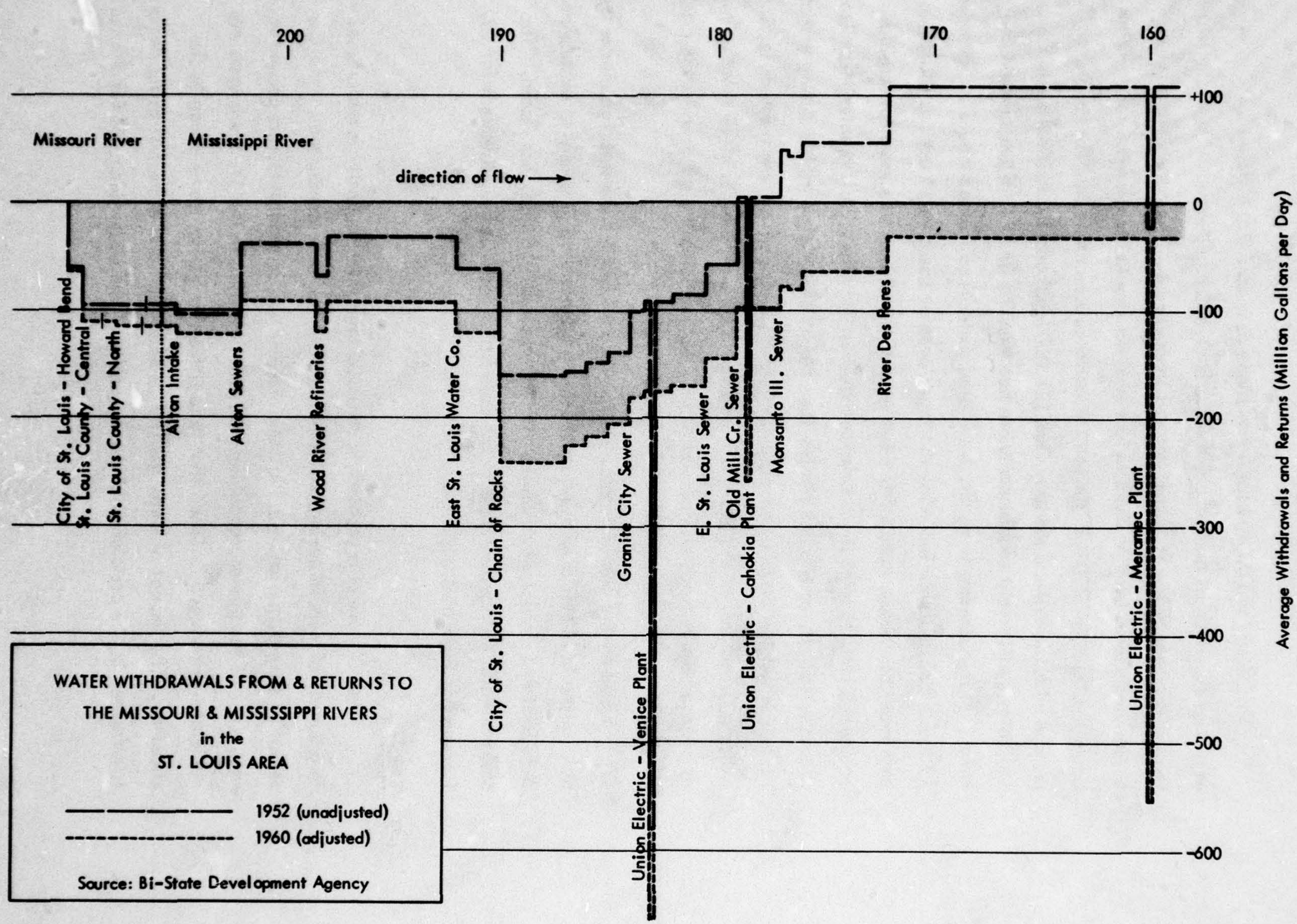
of the Missouri, and a large number of smaller reservoirs on numerous tributaries.[35] Fort Peck Reservoir was completed in 1938, four others were placed in operation during the '50's, and the remaining one will be completed during the early '60's. Water is stored in these reservoirs during the late winter, spring, and early summer to be released for irrigation and power production, and to maintain minimum flows downstream for navigation and for dilution purposes during normally low-water periods. Although some of the water diverted for irrigation is lost through evaporation and transpiration, much of it is returned to the river through seepage. The navigation releases will obviously help to raise the minimum flows during the navigation season. It has been estimated that during the drought years of the middle '50's, as much as half of the total streamflow of the Mississippi at St. Louis during the months of September and October was attributable to releases from the Missouri reservoirs.[36] As pointed out previously, since 1940 no daily flow less than 50,000 cfs has been recorded on the Mississippi River at St. Louis during the May to September period.

<u>Re-use</u>

It should be emphasized that the major portion of the withdrawals for municipal and industrial uses is non-consumptive. On the order of 99% of the water withdrawn for cooling purposes is returned to streams. About 90% of the municipal withdrawal is likewise returned to streams and ground water basins and hence is available for further use. For industrial uses other than cooling, the return flows vary, but generally they are between 85% and 95% of the withdrawals. The basically non-consumptive nature of municipal and industrial demands means that the return flows are available for re-use by organizations downstream -- both within the St. Louis area and beyond. How significant these return flows will be depends upon the points at which the withdrawals are made in relation to the points of return flow. These are not always easy to determine. From the best available source of information on St. Louis area water supply and pollution problems,[37] estimates have been obtained for the average amount of effluent discharged from the major outfall sewers in the St. Louis area in 1952, as well as for the water withdrawals. From these data, a

graph has been prepared showing the cumulative effect of major surface water withdrawals and returns -- those averaging more than 5 mgd. (See Figure 6.) The situation in 1952, as reflected by these data, is indicated by the upper dashed line. One immediate observation is that return flows are greater than surface water withdrawals: the amount of surface water available downstream from St. Louis after all of the area users have been satisfied is greater than the amount available upstream before any users in the area have made withdrawals. This effect might be due to (1) inaccurate estimates of withdrawals, (2) measurement of return flow during periods which were not typical of the whole year, (3) contributions to return flow of water withdrawn from the alluvial materials of the American Bottoms which is then discharged into the sewers after being used for industrial purposes,[38] (4) inflows resulting from local precipitation, (5) water withdrawn from the Meramec River but returned to sewers emptying into the Missouri or Mississippi, and (6) some combination of the preceding.[39] Assume, for the purposes of argument, that reasons (3), (4), and (5) account for none of the discrepancy. Figure 6 would then have to be adjusted for errors of estimation or measurement. The lower (short dashed) line in Figure 6 shows withdrawals and returns, using 1960 estimates for withdrawals, and adjusting returns from outfall sewers to equal 90% of the total surface water withdrawals (other than those of Union Electric Company). This line depicting the balance between average withdrawals and returns at any point along the river, nowhere dips below -700 mgd. Therefore, a flow of 700 mgd would be sufficient to provide for all the uses of the St. Louis area (except navigation). Under such conditions, however, without sufficient flow to provide the desired dilution water, the water downstream from the outfall sewers would be of extremely poor quality, assuming present lack of treatment facilities. Fortunately, for those uses in which water quality (other than temperature) is important, a large portion of the withdrawals are made above the point of any major source of waste discharge, and the major remaining withdrawals are made in the reach which is affected by only the sewers of Alton and Wood River -- which contribute only about 10% of the total sewage flow, and a smaller proportion of the total pollutants.[40]

Figure 6


River Miles Above the Mouth of the Ohio
200
190
180
170
160
+100
0
-100
-200
-300
-400
-500
-600
Average Withdrawals and Returns (Million Gallons per Day)
Missouri River
Mississippi River
direction of flow
City of St. Louis - Howard Bend
St. Louis County - Central
St. Louis County - North
Alton Intake
Alton Sewers
Wood River Refineries
East St. Louis Water Co.
City of St. Louis - Chain of Rocks
Granite City Sewer
Union Electric - Venice Plant
E. St. Louis Sewer
Old Mill Cr. Sewer
Union Electric - Cahokia Plant
Monsanto Ill. Sewer
River Des Peres
Union Electric - Meramec Plant
WATER WITHDRAWALS FROM & RETURNS TO
THE MISSOURI & MISSISSIPPI RIVERS
in the
ST. LOUIS AREA
1952 (unadjusted)
1960 (adjusted)
Source: Bi-State Development Agency

This figure of 700 mgd total requirements means that a flow of water equal to somewhat less than half of the total withdrawals (1,620 mgd) would be sufficient to satisfy the water needs of the St. Louis area on the average. The percentages (of peak demands to minimum flows) used in the previous analysis should therefore be reduced accordingly. Using the figure of 700 mgd for total water requirements in the St. Louis area, a comparison with the critical monthly flow (21,000 mgd) and the critical daily flow (10,000 mgd) indicates that present requirements are between 3% and 7% of the critical minimum flows. Stated another way, St. Louis area water requirements could be increased 15 to 30 times without incurring shortages even at the critical periods (based on past records). When account is taken also of the effects of streamflow regulation on the critical flows of the Mississippi River at St. Louis, still greater increases are possible. If, as appears likely, the amount of water available during critical periods is roughly doubled because of streamflow regulation, the non-navigational water requirements of the St. Louis area could be on the order of 50 times as great as present requirements without exceeding the available supply even at the critical periods.

Based on the previous data, it appears obvious that the water resources available in the St. Louis area are quantitatively adequate to meet a vast expansion in industrial and municipal demands. As the Geological Survey has stated, "The surface water supply available to the area far exceeds the requirements for any foreseeable industrial expansion."[41]

Quality

What is more of a problem in the area than water quantity is water quality. In a survey of manufacturing plants in the St. Louis area conducted by the Conservation Foundation and the National Association of Manufacturers about ten years ago, 40% of the plants responding said that pollution in the St. Louis area was moderate or serious.[42] Since that time little change has taken place in the situation. The impact of water quality on municipal and industrial water demands is reflected in the costs of making the quality of the water adequate for the various

purposes for which it is to be used. Almost all water supplies in the St. Louis area, except those used for cooling, are treated before use, whether the source is surface or ground water. Since surface water for industries is available in large quantities from the rivers at zero cost at their intakes, the cost of self-supplied industrial water consists only of treatment costs. Likewise the cost of surface water at the intakes of the plants of the city of St. Louis, the St. Louis County Water Company, and the East St. Louis and Interurban Water Company is zero.[43] The cost of water supplied to customers in 12 large U. S. cities in the late 1950's is shown in Table 4. St. Louis is near the top of the list. Only three large cities, Cleveland, Chicago, and Detroit, (all located on the Great Lakes) had cheaper water rates. Although St. Louis water rates have increased since this list was compiled, so have the rates of several other cities -- the relative order remains approximately the same.[44] Cost of supplies from ground and alluvial water sources varies with the depth to water, aquifer productivity, quality of the water, and the desired degree of treatment. According to the St. Louis Chamber of Commerce,[45] "a reliable estimate for pumping, aerating, filtering and chlorination ranges between three and four cents per 1,000 gallons." These water costs, to municipal and industrial users, are in line with those in other major metropolitan areas.

From the foregoing it should be apparent that the water resources of the Meramec are small, quantitatively, in comparison to those of the near-by Missouri and Mississippi Rivers -- the average daily flow of the Meramec being about 2% of that of the Mississippi at St. Louis. Nor is the quality of Meramec water significantly different from that of the Missouri and Mississippi water from the standpoint of treatment costs. In fact, the expense of treating Meramec River water appears to be slightly greater than that of treating Missouri or Mississippi water. Based on a rough estimate for 1960, Meramec River water costs about one dollar more for each million gallons treated than does Missouri River water.[46] Although the Meramec contains less sediment, the sediment is of a type more difficult to remove than that of the Missouri and Mississippi. Similarly, the magnesium-type hardness of Meramec water is more difficult to remove than the calcium-type hardness of the other surface supplies.

Table 4

COMPARATIVE WATER RATES
1957 (?)

Annual Metered Water Bills in 12 Largest Cities for
Selected Volumes of Water - 5/8 Inch Meter

City	10,000 Cu. Ft.	Rate/1000 gals.
Cleveland	$ 10.40	$ .138
Chicago	12.60 [a]	.158
Detroit	12.08	.161
St. Louis	14.60	.195
Philadelphia	14.70	.196
New York	15.00	.201
Washington	15.08	.201
Boston	20.00	.266
Los Angeles	21.76 [a]	.289
Pittsburgh	28.92	.385
Baltimore	25.00	.333
San Francisco	34.30	.456

[a] Miscellaneous service charges included.

Source: Philadelphia Bureau of Municipal Research, Pennsylvania Economy League, unpublished memorandum.

Taste and odor problems, resulting from sanitary and biological water quality, appear to be the major objection to Missouri and Mississippi waters. Improvements in these aspects of water quality can be expected to result from the construction of sewage and waste treatment facilities by the larger upstream cities and industries.[47] Thus, from neither a quantity nor from a quality standpoint does Meramec water have any inherent advantage over the alternative sources, as far as meeting the industrial and municipal demands in the St. Louis area is concerned.

Local requirements

However, the Meramec as a source of supply does have advantages in relation to local demands. The growth of the St. Louis urbanized area is predominantly westward -- away from the Mississippi River. These newly built-up areas could be supplied from the Mississippi, but because of the costs involved in transporting water it may prove -- and already has proved -- advantageous to look to other sources of supply. To the northwest, where the most intensive development will probably take place because of the more level land, St. Charles County and northern St. Louis County can be supplied from the Missouri River without difficulty. To the southwest, hilly land limits the intensity of development. Parts of the two counties involved (eastern Jefferson County and southeastern St. Louis County) are closer to the Mississippi than to the Meramec or any of its major tributaries, and could probably be supplied most economically from the Mississippi. The western part of Jefferson County and the southwestern part of St. Louis County, however, lie largely within the Meramec Basin, and would probably find Meramec water the most economical source of supply. For example, the decision to locate the newest plant of the St. Louis County Water Company on the Meramec was based on minimizing distribution costs to customers of the company in the southern part of St. Louis County. As demands continue to increase in that portion of the St. Louis area and in the lower Meramec Basin, the economic advantages of the water resources of the Meramec to serve those areas are likely to increase.

The population of this area might reach 500,000 by the year 2000 (see population estimates in Table 2). Assuming an average demand of 140 gallons

per person per day, a flow of 70 mgd would be required.[48] It is this segment of the St. Louis area water demand which might reasonably be met by Meramec Basin water. This possible average demand of 70 mgd approaches the limit of 127 mgd set by the minimum recorded daily streamflow of the Meramec at Eureka and surpasses the limit set by the "low-flow requirements" of the stream. Under conditions of maximum demand the problem will be more critical. These difficulties, should they arise, could be ameliorated by increasing the low flows of the Meramec with releases of water impounded in upstream reservoirs. The problem is discussed at greater length in the final section of this chapter.

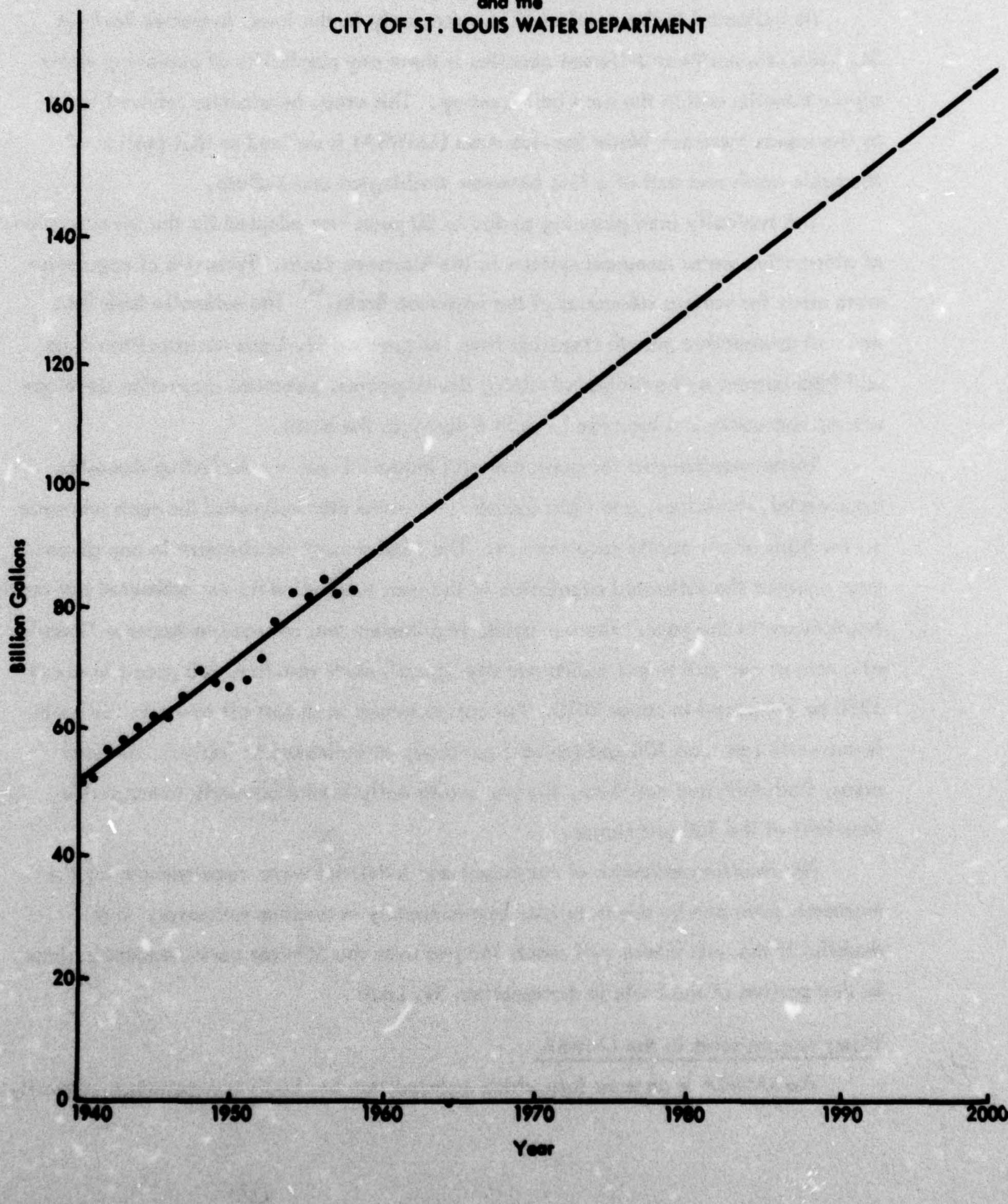
Future trends

Although the basic data included in Table 3 refer to water withdrawals in the St. Louis area for the early 1950s, the additional withdrawals which are now occurring in the area would not alter the water supply picture significantly, either in terms of the relative abundance of water in relation to demand or in terms of relative costs of treating Meramec water compared to Missouri and Mississippi water.

Gross water requirements for the city of St. Louis and St. Louis County water systems combined have increased by approximately 50% during the past 20 years, as shown on Figure 7. If this rate of increase were to continue for the next forty years, the water requirements of these two systems would about double between now and the end of the century. However, the withdrawals by the city department and the County Water Company comprise only about 15% of the total water withdrawals in the St. Louis area for all purposes. Assuming the same proportion were to exist at the end of the century, total withdrawals in the St. Louis area would total slightly more than 3,200 mgd. This would represent less than 3% of the average daily flow of the Mississippi River at St. Louis and about 28% of the recorded minimum flow. At this time there is no way of knowing how valid is the assumption of doubling of demand in the next forty years. What the above does show however, is that, even with doubling or quadrupling of industrial and municipal water requirements in the St. Louis area, there will be adequate supplies of water.

Figure 7

ANNUAL WATER WITHDRAWALS
of the
ST. LOUIS COUNTY WATER COMPANY
and the
CITY OF ST. LOUIS WATER DEPARTMENT



Water Supply Benefits in the Lower Meramec Area

Municipal and industrial water requirements in the Meramec Basin

As indicated in the previous discussion, only in the lower Meramec Basin in St. Louis and northern Jefferson counties is there any possibility of achieving water supply benefits within the next half-century. This area, hereinafter referred to as the Lower Meramec Water Service Area (LMWSA) is defined as that portion of the basin north and east of a line between Washington and DeSoto.

The typically used planning period of 50 years was adopted for the investigation of alternative water resources systems in the Meramec Basin. Estimates of population were made for various sub-areas of the Meramec Basin.[49] The estimates took into account prospective growth stemming from the growing St. Louis Metropolitan Area and from current and anticipated mining developments, potential recreation developments, and continued increase in light industry in the basin.

Water requirements for municipal and industrial use -- including domestic, commercial, municipal, and light industry -- were then estimated for each sub-area on the basis of per capita requirements. The total annual requirement in any given year equaled the estimated population in the year multiplied by the estimated per capita requirement in the year. The per capita requirement was assumed to increase linearly, at a rate of one gallon per capita per day (gpcpd) each year, from 100 gpcpd in about 1970 to 140 gpcpd in about 2010. Per capita intake in almost all towns in the basin is currently less than 100 gpd (gallons per day), as indicated in Table 5. In rural areas, both farm and non-farm, the per capita daily intake currently averages less than half of the 100 gpd figure.

The resulting estimates of municipal and industrial water requirements for the Meramec Basin can be characterized approximately as medium estimates. It is doubtful if the unit intake will reach 140 gpd over the 50-year period except perhaps in that portion of the basin in metropolitan St. Louis.

Water requirements in the LMWSA

The LMWSA is an area into which metropolitan St. Louis is expanding, primarily

Table 5

WATER WITHDRAWAL FOR CITIES IN AND ADJACENT TO MERAMEC BASIN, 1958

City	County	Population Served	Source[a]	Quantity[b] Withdrawn (mgd)	Per Capita Withdrawals (gpd)[c]
Cuba	Crawford	960	G	.08	83
Steelville	Crawford	1,150	G	.057	49
Salem	Dent	2,760	G	.165	60
Gerald	Franklin	500	G	.025	50
St. Clair	Franklin	1,580	G	.07	44
Sullivan	Franklin	3,100	G	.16	52
Union	Franklin	2,912	S	.28	96
Pacific	Franklin	1,690	G	.05	30
Cedar Hill	Jefferson	160	G	.008	50
Hillsboro	Jefferson	350	G	.040	114
St. Louis - County	St. Louis	600,000	S	47.8	80
Valley Park	St. Louis	3,000	A	.2	67
Potosi	Washington	2,450	G	.12	49
Eureka	St. Louis	1,500	G	.4	270
St. Louis - City		747,127	S	181.1	242
De Soto	Jefferson	4,000	G	.700	175
Crystal City	Jefferson	4,000	G	.283	71
Festus	Jefferson	5,000	G	.250	50
Herculaneum	Jefferson	1,600	G	.08	50
Pevely	Jefferson	420	G	.008	19

[a]Source of Supply
S - surface water
G - ground water from bedrock aquifers
A - ground water from alluvial aquifers

[b]annual average in million gallons per day

[c]gallons per day

Source of data: U.S. Geological Survey

for residential use but also for some industrial use. In this area the confined ground water aquifers produce smaller yields than in the remainder of the basin, and are relatively highly mineralized. In addition, the shallow unconfined aquifers in the urbanizing areas are increasingly subject to contamination. Hence, the LMWSA will be dependent on surface water supplied to meet future water requirements for municipal and industrial uses in the area.

By 2000 it is estimated that in the LMWSA a population of about 500,000 will require water along with the associated commercial, public, and light industrial activities. Growth in population and in water requirements is expected to increase more rapidly in the post-1980 period than in the pre-1980 period.

The St. Louis County Water Company, which currently provides water to that portion of the LMWSA which already meets it municipal and industrial water requirements from surface water, has definite plans for expansion of its water treatment and distribution system. Currently the Meramec Plant of the County Water Company is operating about six months of the year. It is anticipated that the full capacity of the plant will be utilized within several years.

The population to be served from the Meramec is shown in the table along with the assumed per capita daily requirement, the average daily requirement, and the average requirement in the maximum month. As indicated previously, the per capita daily requirement is assumed to increase linearly from 100 gpcpd in 1970 to 140 gpcpd in 2010. Population is assumed to increase logarithmically.

Table 6
WATER REQUIREMENTS IN THE LMWSA

Year	Population to be Served* (thousands)	Per Capita Requirement gpd	Average Annual Requirement mgd	Average Requirement in Maximum Month mgd
1960	100	90	9	11.7
1970	150	100	15	19.5
1980	225	110	24.7	32.1
1990	330	120	39.6	51.5
2000	500	130	65	84.5
2010	750	140	105	136.5

*Based on a logarithmic increase from 100 (1960) to 500 (2000)

The average requirement in the maximum month is based on the monthly distribution of withdrawals by the St. Louis County Water Company for the period, 1951-59.[50] The distribution by months in terms of percent of the average annual requirement is shown in Table 7. The requirement in the maximum month, July, thus represents about 130% of the average annual requirement and is the design capacity assumed in the computation of benefits from meeting water requirements in the LMWSA. Daily water requirements in excess of this capacity are assumed to be met from storage in the distribution system.

Table 7

MONTHLY WATER REQUIREMENTS IN THE LMWSA

Month	% of Average Annual Requirement	Month	% of Average Annual Requirement
October	103	April	85
November	92	May	98
December	94	June	116
January	78	July	130
February	76	August	129
March	79	September	120

Benefits from meeting water requirements in the LMWSA

The estimated requirements for municipal and industrial water can be met from any one or a combination of alternative sources, one of which would be releases from reservoirs in the Meramec Basin. Releases would logically be made into the existing stream channels from which withdrawals would be made in the LMWSA, as is done at present at the Meramec Plant of the St. Louis County Water Company. Although a reservoir on the Big River might have some slight locational advantage in serving northern Jefferson County, it is assumed that that area could also be served from the Meramec River. This assumption is reasonable, since the County Water Company currently is supplying water from the Meramec River to a portion of northern Jefferson County south of the Meramec River. While direct

withdrawals from the Big River might result in lower distribution costs, withdrawals from the Meramec River would have the advantage of economies of scale with respect to water treatment costs.

In evaluating benefits which could be attributed to Meramec Basin reservoirs in meeting water requirements, the cheapest alternative source of an equivalent supply -- the same amount of water of the same quality with the same time distribution -- was used as a measure of these benefits, in accord with traditional practice. For the LMWSA, the cheapest alternative source of water is ground water from the alluvial materials along the lower Meramec River. However, there is an upper limit to the amount of water available from this source under present conditions, a rough estimate of the potential yield being about 50 mgd.[51]

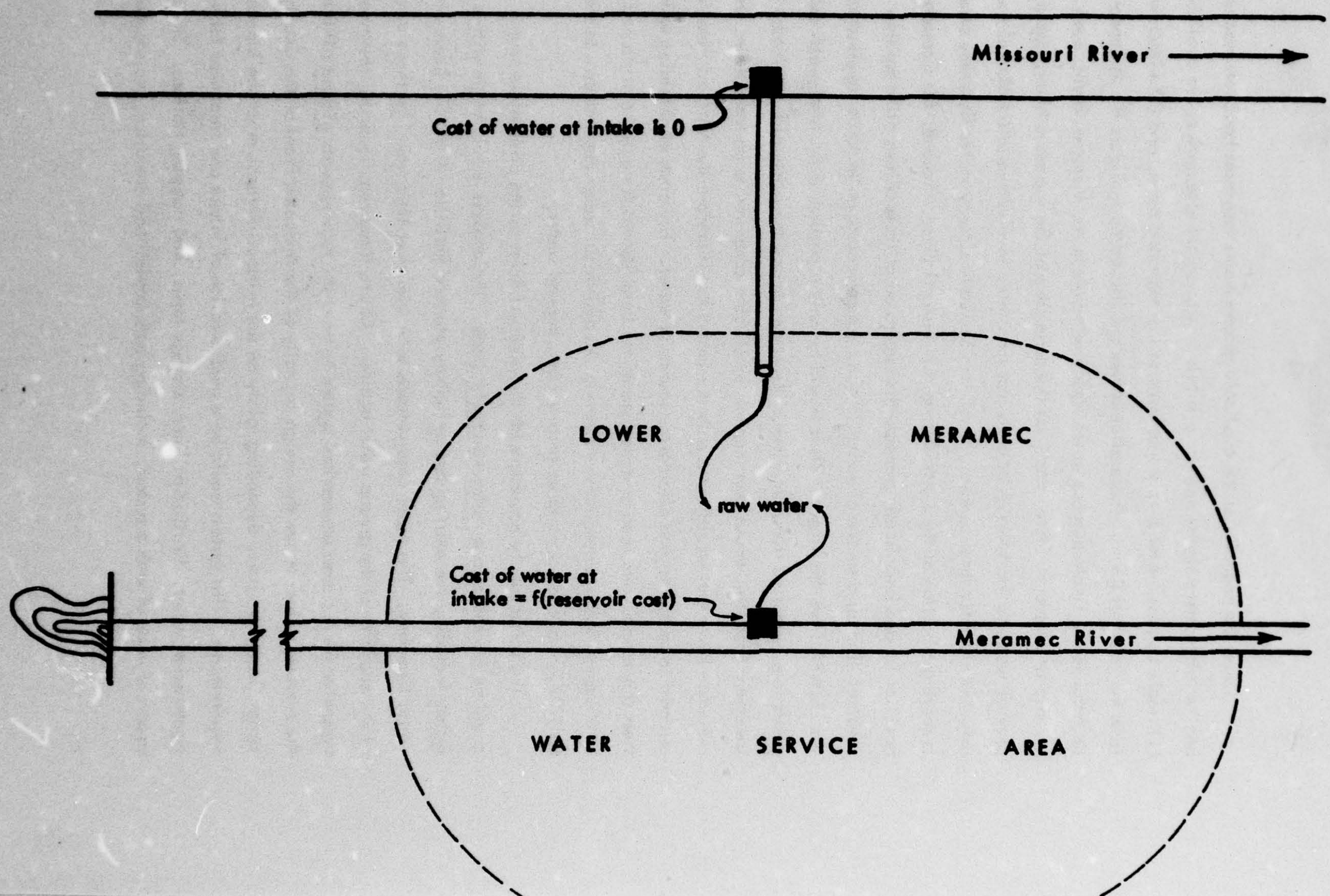
In computing benefits using ground water as the alternative source, it is assumed that the distribution system would be about the same as the distribution system if water from Meramec Basin reservoirs were the source.[52] Water treatment costs for ground water should be significantly less than those for Meramec River surface water. Ground water from the alluvial materials along the Meramec River is cooler and the temperature range throughout the year is less than that for surface water.[53] Turbidity of the ground water is virtually negligible. Bacteriological quality of the ground water is much better than that of the surface water, even when some portion of the ground water is actually induced recharge from the river. Hardness tends to be somewhat higher for ground water. Major treatment costs for surface water stem from turbidity and sanitary quality problems. In combination, the various factors should result in lower treatment costs for the ground water. With respect to operating costs, the pumping lift for ground water as a source is of course greater than the head against which the intake pumps for a surface water source would operate. However, the pumping lift for wells relatively close to the river is on the order of only 20 to 40 feet.

Without extensive analysis, it appears reasonable to assume that the operating costs -- differential pumping costs plus treatment costs for ground water compared with treatment costs for surface water -- are about equal.[54]

Once the capacity of the available ground water resources has been reached,[55] another alternative source must be utilized. Two logical alternatives are available: (1) single purpose water supply reservoirs in the Meramec Basin, and (2) withdrawals from the Missouri River. These alternatives are illustrated in Figure 8. It appears doubtful that a single purpose water supply reservoir in the Meramec Basin, such as one at Meramec State Park on the main stem of the Meramec River, could provide water to the LMWSA at costs less than those involved in utilization of the Missouri River for three reasons. First, the St. Louis County Water Company already is serving a portion of the LMWSA from the Missouri River. Second, the Company has sites for and has already planned the expansion of its facilities utilizing the Missouri River as a source of water. Third, the amount of water to be supplied to the LMWSA from the Missouri River would be only a portion of the total water requirements to be supplied from the Missouri River and hence the Missouri River intake and treatment facilities would have economies of scale compared to an installation on the Meramec River that would serve only the LMWSA. Therefore the Missouri River was assumed to be the second alternative source of water. The costs of obtaining water from this source were used as a measure of the benefits which could be attributed to Meramac Basin reservoirs from meeting the additional water requirements in the LMWSA, over and above those supplied from ground water.

The water supply benefits with the Missouri River as the alternative source could be measured on a without and with basis. The analysis would begin with a system including the existing and definitely planned facilities of the St. Louis County Water Company. The water requirements to be met over time would be those in excess of the capacity of the ground water aquifer. Given those requirements, costs would be computed for the most economical system to meet the requirements without utilizing the Meramec River above the design capacity of the Meramec Plant of the County Water Company, i.e., depending solely on the Missouri River to meet the incremental requirements. This system would be a configuration of intake and treatment facilities, transmission mains, distribution lines, storage tanks, and pumping stations. The time stream of costs of such a system, including both capital and operation, maintenance,

ALTERNATIVE WATER SUPPLY SOURCES — LOWER MERAMEC AREA



and replacement (O M & R), would represent the cost of water without the incremental use of the Meramec River.

Taking the same assumptions about magnitude and location of water requirements in the LMWSA, costs would be computed for the most economical system with additional use of the Meramec River. Since the Meramec River is closer to the LMWSA, presumably the most economical system would be achieved by utilization of the water source closest to the area of use. This system would include the existing and planned facilities of the County Water Company plus whatever additions would be necessary to meet the requirements -- a different configuration of intake and treatment facilities, transmission mains, distribution lines, and so on. The difference between the time streams of costs without using the Meramec River as an incremental source and with using the Meramec River as an incremental source, would be the time stream of benefits attributable to surface water reservoirs in the Meramec Basin from meeting water requirements in the LMWSA. Implicit is the assumption on which the County Water Company has based the design of its Meramec Plant, that is, 35 mgd is the maximum permissible withdrawal from the Meramec River without streamflow augmentation.

Specific water supply benefits

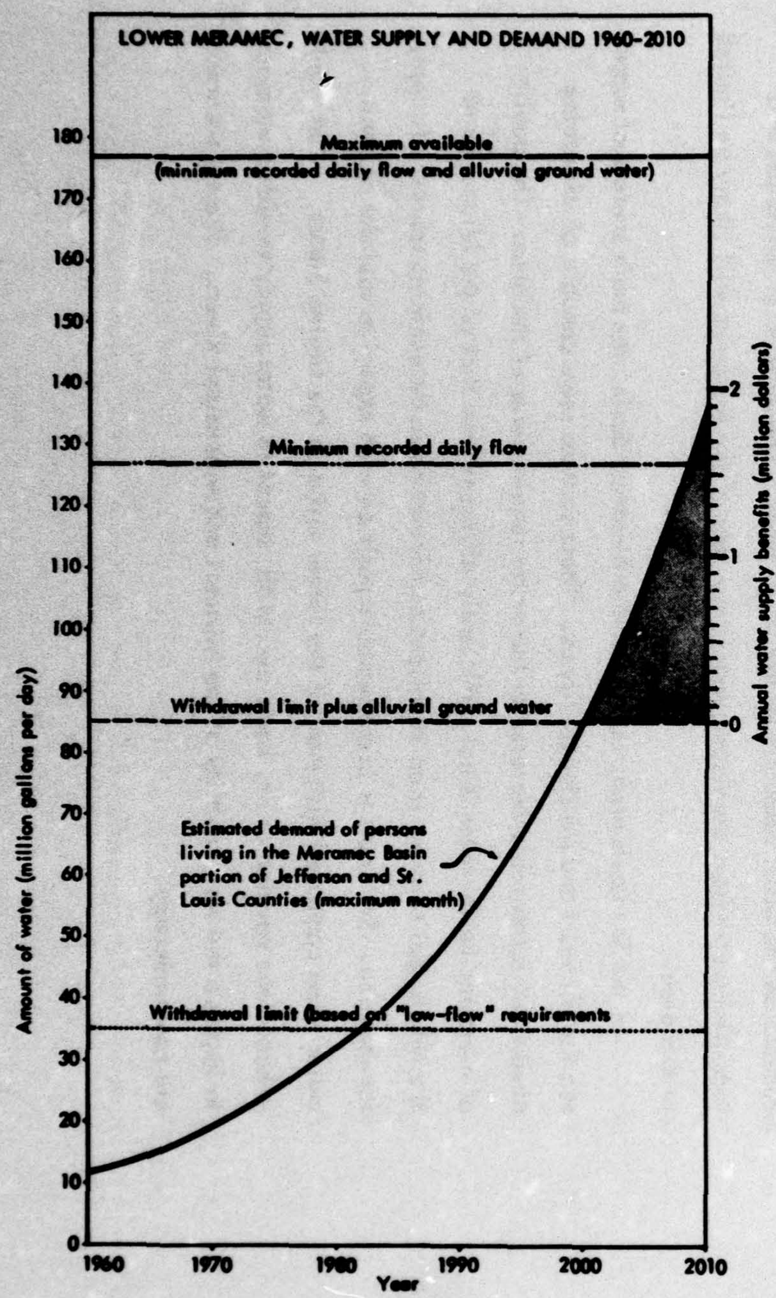
The cheapest alternative source of supply, ground water, was assumed to be utilized first, up to the capacity of the alluvial materials. As water requirements grew over time, additional wells were assumed to be drilled as needed to meet the requirements. Since treatment costs were estimated to be equal for surface and ground water, no benefits would accrue from using surface water released from reservoirs rather than ground water. Therefore, no benefits are postulated until the capacity of the presently available surface and ground water supplies is reached.

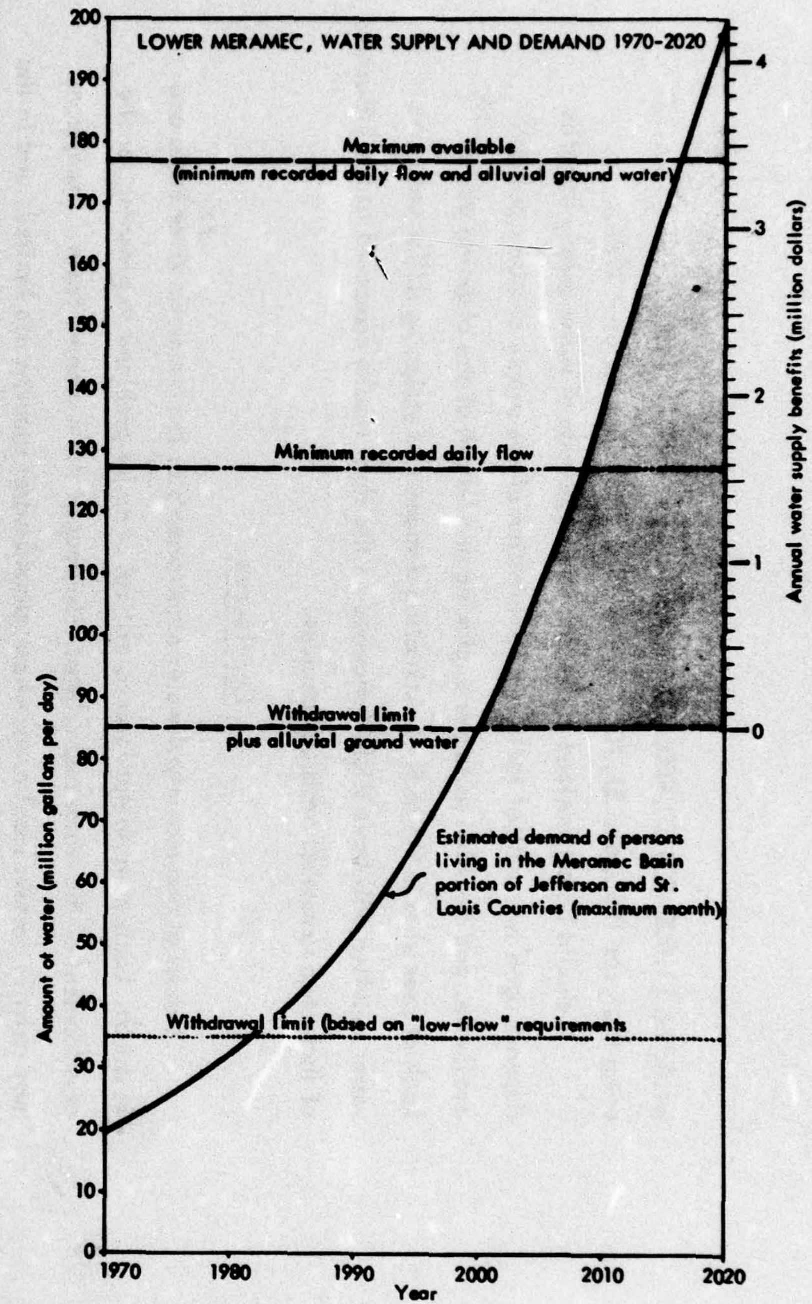
When the capacity of the ground water resources was reached, the incremental water requirement to be met was assumed to be obtained from the Missouri River. To obtain specific figures for the cost of the Missouri River alternative would require a detailed analysis of extensive water distribution systems under the two different sets of conditions indicated previously. Since such an extensive study was not possible,

the alternative cost was based on the current minimum rate of the St. Louis County Water Company to large users and on possible economies of scale in providing the relatively large quantities of water needed in the later years of the 50-year period. A unit cost of $100 per million gallons was assumed for the Missouri River alternative, regardless of the quantity of water required. The effect of this simplification is mitigated somewhat by the fact that the large requirements from the Missouri River, and hence the large benefits, occur in the later years of the 50-year period. The result is a lower present value of benefits than if the Missouri River alternative were needed in the early years. The water supply benefit in any given year, for that portion of the requirement met from the Missouri River, is the total amount supplied in the given year times the unit cost ($100 per mg).

Figure 9 shows the relationship between the supply of water and the probable demand in the lower Meramec area to the year 2020, as well as the resulting time stream of benefits from meeting water requirements, i.e., water supply benefits. These benefits can be attributed to any reservoir system in the Meramec Basin which supplied the estimated water requirements over the 50-year period. The benefits shown are based on the assumption that the available supply is equal to the withdrawal limit (35 mgd) plus the amount available from ground water (50 mgd) -- a total of 85 mgd. The available supply will probably be exceeded in the year 2000. The two parts of Figure 9 demonstrate the critical importance which the choice of a planning period plays in determining the amount of benefits to be derived. The graph on the left shows the benefits to be derived during the period 1960-2010. The figure on the right shows the benefits if the planning period were 1970-2020. In each graph, the shaded area is proportional to the benefits. Table 8 shows the time stream of benefits to be derived using three different planning periods. If 1965 rather than 1960 is used, the benefits are about twice as great. If 1970 rather than 1960 is used, benefits are about five times as great. The proper period to use is dependent upon when the investment of funds begins. If planning progresses fairly rapidly, use of the year 1965 would be most reasonable. Certainly no earlier beginning date is justified. Using interest rates of 4% and 2.5% respectively, the present value of water supply benefits

Figure 9


LOWER MERAMEC, WATER SUPPLY AND DEMAND 1960-2010
Maximum available
(minimum recorded daily flow and alluvial ground water)
Minimum recorded daily flow
Withdrawal limit plus alluvial ground water
Estimated demand of persons living in the Meramec Basin portion of Jefferson and St. Louis Counties (maximum month)
Withdrawal limit (based on "low-flow" requirements
Amount of water (million gallons per day)
Annual water supply benefits (million dollars)
Year
1960
1970
1980
1990
2000
2010


LOWER MERAMEC, WATER SUPPLY AND DEMAND 1970-2020
Maximum available
(minimum recorded daily flow and alluvial ground water)
Minimum recorded daily flow
Withdrawal limit
plus alluvial ground water
Estimated demand of persons living in the Meramec Basin portion of Jefferson and St. Louis Counties (maximum month)
Withdrawal limit (based on "low-flow" requirements
Amount of water (million gallons per day)
Annual water supply benefits (million dollars)
Year
1970
1980
1990
2000
2010
2020

would be $1,400,000-$2,800,000, using the year 1960; $3,600,000-$6,900,000 using the year 1965; and $7,700,000-$13,300,000 using the year 1970.

It should be emphasized again that the magnitude of water supply benefits depends upon two critical factors; determination of the supply of water presently available, and decision as to the beginning and length of the planning period.[56] Lack of precision in methods of estimating demand and assigning dollar values to water supplied will have slight influence on the final results compared to the influence of these two somewhat arbitrary choices.

Conclusions

Industrial and municipal water requirements in the Meramec River Basin and in the St. Louis area do not loom as critical or major problems in planning for the development of the water and related resources of the Meramec Basin. Exceptions may exist in certain local areas where ground water supplies are limited, and in the lower basin where the outward growth from the city of St. Louis will place increasing demand on the water resources of the lower basin. The market for municipal and industrial water from developed water resources of the Meramec will likely be limited to this area.

In the St. Louis area, outside of the Meramec Basin, the main sources of supply are the Missouri and Mississippi Rivers. These sources seem capable of absorbing almost any foreseeable increase in the water requirements of the area. The quality of Meramec Basin water is not sufficiently different from that of the Missouri and the Mississippi to make it an important consideration in determining sources of supply for the area. St. Louis is in a favorable position with regard to supplies of fresh water when compared with most of the larger cities in the United States. What would enhance the position of St. Louis most with respect to water supply would be measures to improve the water quality of the Missouri and Mississippi Rivers. These measures are now underway.

Table 8

WATER SUPPLY BENEFITS

Period (Year)	Additional Water Requirement[a] (Million Gallons Per Day)	Total Benefits During Period	Average Annual Benefits	Present Value (at 2.5%)			Present Value (at 4%)		
				Discounted to 1960	Discounted to 1965	Discounted to 1970	Discounted to 1960	Discounted to 1965	Discounted to 1970
1960-2000	0	0	0	0	0	0	0	0	0
2000-2005	12	2,190,000	438,000	760,000	860,000	970,000	410,000	490,000	600,000
2005-2010	37	6,750,000	1,350,000	2,070,000	2,340,000	2,640,000	1,030,000	1,250,000	1,520,000
2010-2015	67	12,250,000	2,450,000	0[b]	3,740,000	4,240,000	0[b]	1,860,000	2,270,000
2015-2020	98	17,885,000	3,577,000	0[b]	0[b]	5,470,000	0[b]	0[b]	2,720,000
TOTAL DISCOUNTED BENEFITS				2,830,000	6,940,000	13,330,000	1,440,000	3,600,000	7,110,000

[a]Peak monthly demand minus the available supply

[b]No benefits accrue after the end of the 50-year planning period.

REFERENCES AND NOTES

1. U. S. Geological Survey, Water Supply Paper No. 1561, Surface Water Supply of the United States, 1958; Part 7, Lower Mississippi River Basin (Washington: U. S. Government Printing Office, 1960), p. 28.

2. Missouri Division of Resources and Development, Water Resources (Map) no date.

3. U. S. Geological Survey, Water Supply Paper No. 1561, p. 28.

4. E. A. Roemer, Meramec River Basin Low-Water Study, Sept. 24 to Oct. 1, 1953. A report in the files of the U. S. Geological Survey, Water Resources Division, Rolla, Mo. Measurements were made during a one-week period in 1953 when streams appeared to be at their lowest level in many years because of draught conditions.

5. Ibid., p. 3.

6. Data obtained from the files of the Missouri Division of Health, Jefferson City, Missouri. In general, data are from once-a-year measurements taken during the late 1950's.

7. Data for Fenton from the records of the St. Louis County Water Co. Data for Kirkwood from J. K. Searcy, R. C. Baker, and W. H. Durum, Water Resources of the St. Louis Area, Missouri and Illinois, U. S. Geological Survey. Circular No. 216 (Washington: U. S. Government Printing Office, 1952), pp. 33-37.

8. Searcy, et al., p. 49.

9. Ibid., p. 37. Measurements by city of Kirkwood.

10. Since census figures are compiled with reference to political boundaries rather than drainage basin boundaries, no exact figures can be given. Estimates are by Edward L. Ullman.

11. U. S. Bureau of the Census, Census of Population: 1960. Number of Inhabitants, Missouri. (Washington: 1960).

12. The fast-growing lead mining town of Viburnum probably should be added to this list. Its population at this time is not known, but according to the St. Louis Globe Democrat (Sept. 20, 1959), it is expected to reach 2,000 by the end of 1960.

13. The capacity of the Kirkwood treatment plant is considerably less than the water available from its combined surface and ground water intakes. Thus whenever demand exceeds the capacity of the treatment plant, the additional water required above that capacity is secured from the St. Louis County Water Company.

14. Union Electric's steam generating facilities located at the mouth of the Meramec utilize water withdrawn from the Mississippi.

REFERENCES AND NOTES (continued)

15. Communication from Thomas R. Beveridge, Missouri State Geologist, Rolla, Mo., October 14, 1960. It should be noted that present economic conditions are not considered normal.

16. Estimates by Edward L. Ullman.

17. Missouri Division of Resources and Development, op.cit.

18. Only three major cities (Sullivan, St. Clair, and Union) are located within five miles of the permanent pools of the three reservoirs proposed by the Corps of Engineers in 1949. U. S. Army, Corps of Engineers, Three Reservoirs for Flood Control and Other Purposes, (Appendix I to the Summary Report of the Meramec Cooperative Investigation Field Committee), March, 1947, revised February and August, 1949.

19. Glen J. Hopkins and Joe K. Neel, "Water Quality in the Missouri River," Journal of the Sanitary Engineering Division of the American Society of Civil Engineers, Vol. 84, No. SA 1 (February, 1958), p. 1542-3.

20. Ibid., p. 1542-10.

21. This flow is the lowest recorded at Sappington Bridge, about 30 miles upstream from St. Clair, during the period of record, 1921-1933 and 1943-1958. U.S.G.S., Water Supply Paper No. 1561, p. 20.

22. At the present time, however, in part because the river has been designated a "navigable stream" up to mile 22, withdrawals from the lower Meramec have been limited by the Corps of Engineers to 1/3 - 1/4 of the total flow. Water quality considerations may also have played some part in this limitation.

23. The years 1898-1927 are estimated. See Searcy, et al., p. 10.

24. U. S. Geological Survey, Water Supply Papers No. 1560 and 1561. Surface Water Supply of the United States, 1958; Parts 6-B and 7, Lower Missouri River Basin and Lower Mississippi River Basin (Washington: U. S. Government Printing Office, 1960).

25. Searcy, et al., pp. 41-43.

26. Robert E. Bergstrom and Theodore R. Walker, Groundwater Geology of the East St. Louis Area, Illinois, State Geological Survey, Report of Investigations 191 (1956), 44 pp.

27. Searcy, et al., p. 43.

28. Complete up-to-date estimates are not available. Relatively complete data are available for the years 1950 and 1954 from surveys of the U. S. Geological Survey and the Bi-State Development Agency. More recent data are available for certain of the water users.

REFERENCES AND NOTES (continued)

29. Daily streamflow records have been published by the U.S.G.S. for this station only since this time.

30. While this could be due partly to natural hydrologic variations, it is also due, at least in part, to streamflow regulation on the Missouri which is discussed later.

31. The data on minimum monthly and minimum daily flows were obtained from the U. S. Geological Survey streamflow records for the station, Mississippi River at St. Louis. All supply data for the Mississippi River relate to this gaging station. The daily flow is actually the minimum daily flow recorded during the month of minimum monthly flow. This may or may not be the minimum recorded daily flow for that month over the period of record, but should be a close approximation. Data concerning the seasonal fluctuation of monthly demand (1932-1958) were obtained from the records of the St. Louis County Water Co. Data concerning daily demand fluctuation (1938-1958) were obtained from the city of St. Louis.

32. Based on limited data, variations in demand do not appear to be of the same order of magnitude for the different water systems. The comparisons of peak daily and average annual demands quoted above are typical of the systems of the cities of St. Louis and Alton. The East St. Louis and Interurban Water Company experiences variations of generally lesser magnitude, whereas those of the St. Louis County Water Co. are considerably larger.

33. Municipalities and industries which utilize alluvial water are, in effect, making use of the alluvial materials of the floodplain as a storage reservoir for the water.

34. Of course, the entire 21,000 mgd is not available for withdrawal uses because of navigational requirements.

35. R. J. Pafford, Jr., "Operation of Missouri River Main Stem Reservoirs," Journal of the Waterways and Harbors Division of the American Society of Civil Engineers, Vol. 83, No. WW3 (September, 1957), p. 1370-3.

36. Ibid., 1370-12. About 2/3 of the total projected storage capacity was available by the end of 1956.

37. Bi-State Development Agency, Mississippi River Water Pollution Investigation (St. Louis: 1954), pp. 28-32, 85, a25 - a43.

38. This is water which has, in effect, been withdrawn from underground storage and added to surface flow.

39. It should be pointed out that the indicated return flows exceed the amount of water withdrawn from all sources (other than that withdrawn by Union Electric Co.), and therefore reason (3) could not account for all of the discrepancy.

40. Bi-State Agency, p. 85.

41. Searcy, et al., p. 54.

REFERENCES AND NOTES (continued)

42. The Conservation Foundation, Water in Industry, New York, 1950.

43. That is, no costs for such items as reservoirs and aqueducts are involved in making the water available at their intakes.

44. Latest St. Louis water rates are published by the Chamber of Commerce of Metropolitan St. Louis, Metropolitan St. Louis Industrial Manual (St. Louis, 1960), p. J-9.

45. Chamber of Commerce of Metropolitan St. Louis, The Industrial Water Resources of the St. Louis Area (no date), p. 19.

46. Interview with J. L. Tuepker, St. Louis County Water Company.

47. Sioux City, Omaha, and the municipalities of the Kansas City area approved bond issues for this purpose during 1960 or before. Faced with a suit by the federal government to force compliance with pollution standards, the city of St. Joseph approved a similar bond issue early in 1961 (after two previous defeats). The industries of St. Joseph had previously decided to proceed with plans for separate treatment facilities.

48. This assumed demand of 140 gallons per person per day is a very liberal one. Present per capita daily demand of St. Louis County Water Co. customers is about 80 gallons. Based on less reliable data, the demand of most other cities in the basin is less than 100 gallons per capita per day. Even with allowance for expected increase in per capita demand over time, the assumption of 140 gallons per capita per day should be more than adequate.

49. These estimates were made by Edward L. Ullman.

50. The monthly distribution for the city of Kirkwood Water Plant is similar.

51. Estimate made by L. M. Heckman, Engineer in Charge, Layne-Western Company, Kirkwood, Missouri.

52. This probably would not be strictly true, since wells are flexible and could be located close to "load" centers. On the other hand, because individual well yields are limited, the dispersed location pattern could be carried only so far.

53. Searcy, et al., p. 49

54. This assumption could of course be checked by analyzing the pump and treatment costs involved.

55. Yield is limited because of drawdown. Also, with higher yields, iron precipitation may become a problem.

56. The benefits described herein will accrue only if it is assumed that withdrawals from the Meramec River should be limited to 35 mgd rather than the minimum recorded flow--127 mgd. Before any final determinations are made concerning storage allocations and benefit-cost analysis, a more thorough examination should be made of the reasons and necessity for placing such withdrawal limitations on use of water from the Meramec.

APPENDIX A

GROUND WATER IN THE MERAMEC BASIN

by

Robert D. Knight

The Meramec Basin area in the northern part of the Ozark Region has ample ground water resources except in the extreme northeastern corner of the area where the ground water is mineralized. There is little need for treating the water from deep wells in much of the area if the well construction is correct. Proper construction includes setting of the well casing in grout at a casing depth recommended by the Missouri Geological Survey and Water Resources and above ground construction in accordance with recommendations of the State Division of Health.

The major aquifers in this area are the Roubidoux, Gasconade, Potosi formations and Gunter member of the Gasconade formation. (See Figure 10). In the southeast part of the area, water from older formations is the only ground water available because the Potosi and younger formations crop out or have been eroded away. Generally this means that the water in this part of the basin must be treated, because casing a well in this area would shut out much of the available water. Treatment of the water in this area for public use is mandatory.

Mineralized ground water is present east of a line just east of Ballwin, to east of High Ridge, (Figure 11).

Roubidoux formation

The Roubidoux formation, which averages 125 to 150 feet in thickness over much of the area, is near or at the surface. This formation consists of dolomite with a high percentage of sandstone and chert. When below the surface it is an aquifer for small farm and household use, producing an average of 15 gallons of water per minute. Generally a casing depth to the top of the Roubidoux is sufficient to keep out contamination in this area; however, locally the Roubidoux may have crevices and mud seams and should be cased.

The Roubidoux formation, when at the surface, should be completely cased out and the well drilled into the cherty portion of the Gasconade formation.

Gasconade formation

The Gasconade is characteristically lacking in chert in the upper 50 to 75 feet. This 50 to 75 foot zone is not a water producing horizon.

Below the upper Gasconade noncherty horizon is a zone of cherty dolomite

averaging 200 feet in thickness. The upper 100 feet of this zone contains approximately 50% chert. This zone is a reliable water horizon which averages 10 to 15 gallons of water per minute.

Below the water producing horizons is another chert and dolomite horizon averaging 100 feet thick in which there is very little water.

The Gunter Sandstone or sandy dolomite member is the basal part of the Gasconade formation and averages 25 to 40 feet in thickness. This member produces 40 to 50 gallons of water per minute, however, there are a few instances of production exceeding 75 gallons per minute. Small industries, motels, or other small public facilities utilize the water from the Gunter member.

Eminence formation

Below the Gunter lies the Eminence formation, a dolomite with a relatively low chert content averaging 250 to 300 feet thick. Locally this formation produces some water but not enough to be completely reliable.

Potosi formation

The Potosi formation which directly underlies the Eminence is a reliable large quantity producer which generally furnishes enough water for cities and industries.

The Potosi is a very porous and vuggy, coarsely crystalline dolomite containing as much as 50% silica in the form of chert and quartz druse.

Production ranges from 200 gallons of water per minute to 500 gallons per minute and can be raised to as much as 700 gallons per minute by acidizing.

The thickness of the Potosi averages 300 feet throughout the basin, with the exception of the St. Francois Mountain area in the extreme southeastern part of the basin where it has been partly or completely removed by surface erosion.

All wells in this area should be cased to eliminate possible contamination. Although the practice is not followed in many cases, all wells, mine shafts, and mineral tests that are abandoned should be properly plugged to eliminate any source of ground water contamination.

Table 9

DATA ON GROUND WATER USE

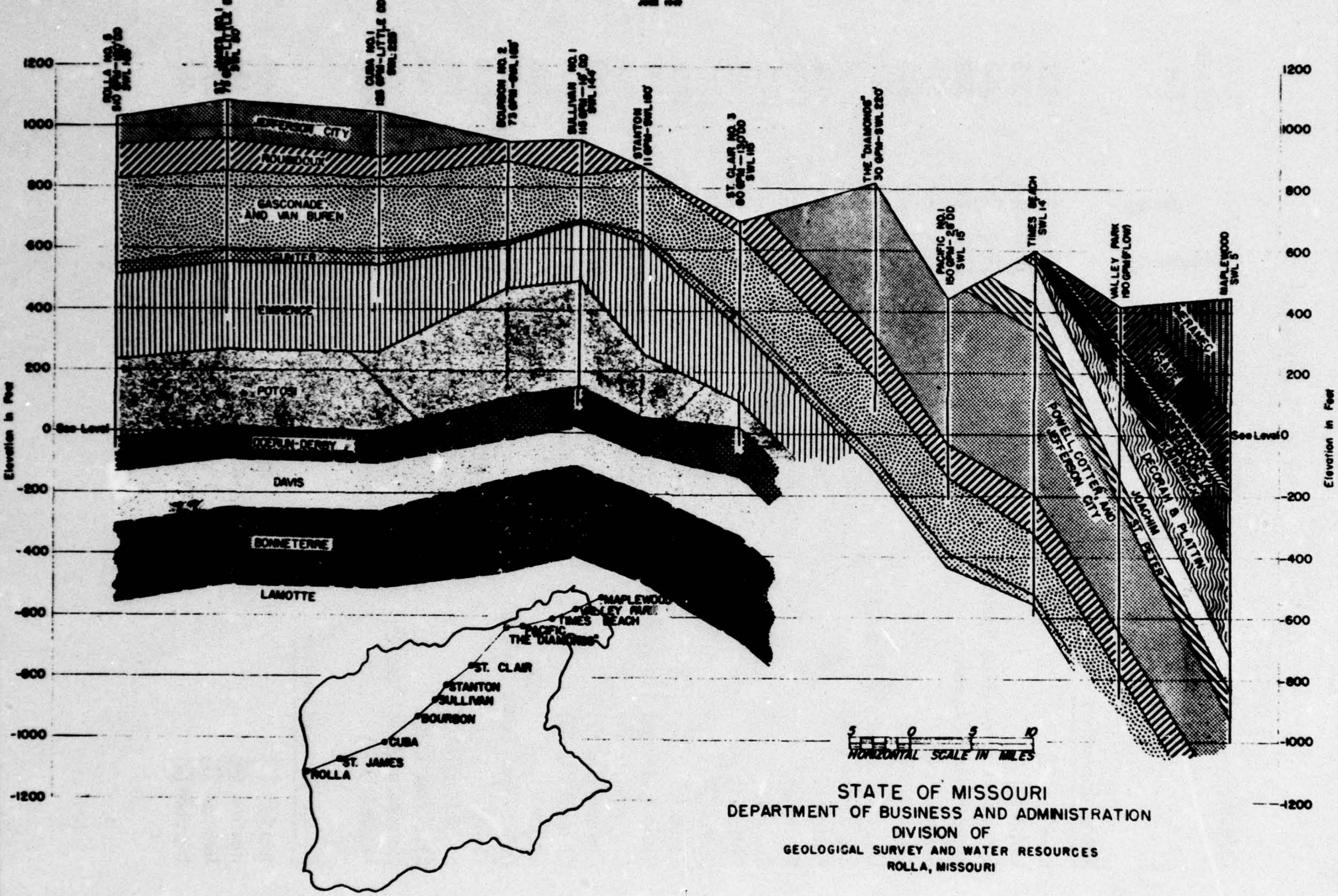
NAME	COUNTY	LOCATION Section	Township	Range	TOTAL DEPTH (feet)	PRODUCTION (gallons per minute)
Roubidoux formation						
Gray Summit (School)	Franklin	12	43N	1E	590	25
U.S. Government (Nike Base)	Franklin	1	42N	2E	680	52
Gasconade formation						
Rosebud (No. 1)	Gasconade	17	42N	4W	508	35
Eureka	St. Louis	35	44N	3E	800	135
Pacific (2)	Franklin	12	43N	2E	765	241
Pacific (1)	Franklin	12	43N	2E	650	150
Cedar Hill (1)	Jefferson	25	42N	3E	650	30
Gunter member of Gasconade formation						
Boys Town of Missouri, St. James	Phelps	22	38N	6W	300	42
Oak Meadow (Country Club)	Phelps	4	37N	7W	550	100
Eminence formation						
Cuba (1)	Crawford	31	39N	4W	602	125
Bible Pres.Ch. (boys & girls camp)	Crawford	26	39N	3W	375	12
St. James (1)	Phelps	20	38N	6W	700	75
Vichy Airport (1)	Maries	2	39N	8W	850	103
Vichy Airport (2)	Maries	6	39N	8W	950	225
Rosebud (2)	Gasconade	17	42N	4W	700	96.5
Cedar Hill (2)	Jefferson	25	42N	3E	902	50
Hillsboro (1)	Jefferson	3	40N	4E	931	65

Table 9 (continued)

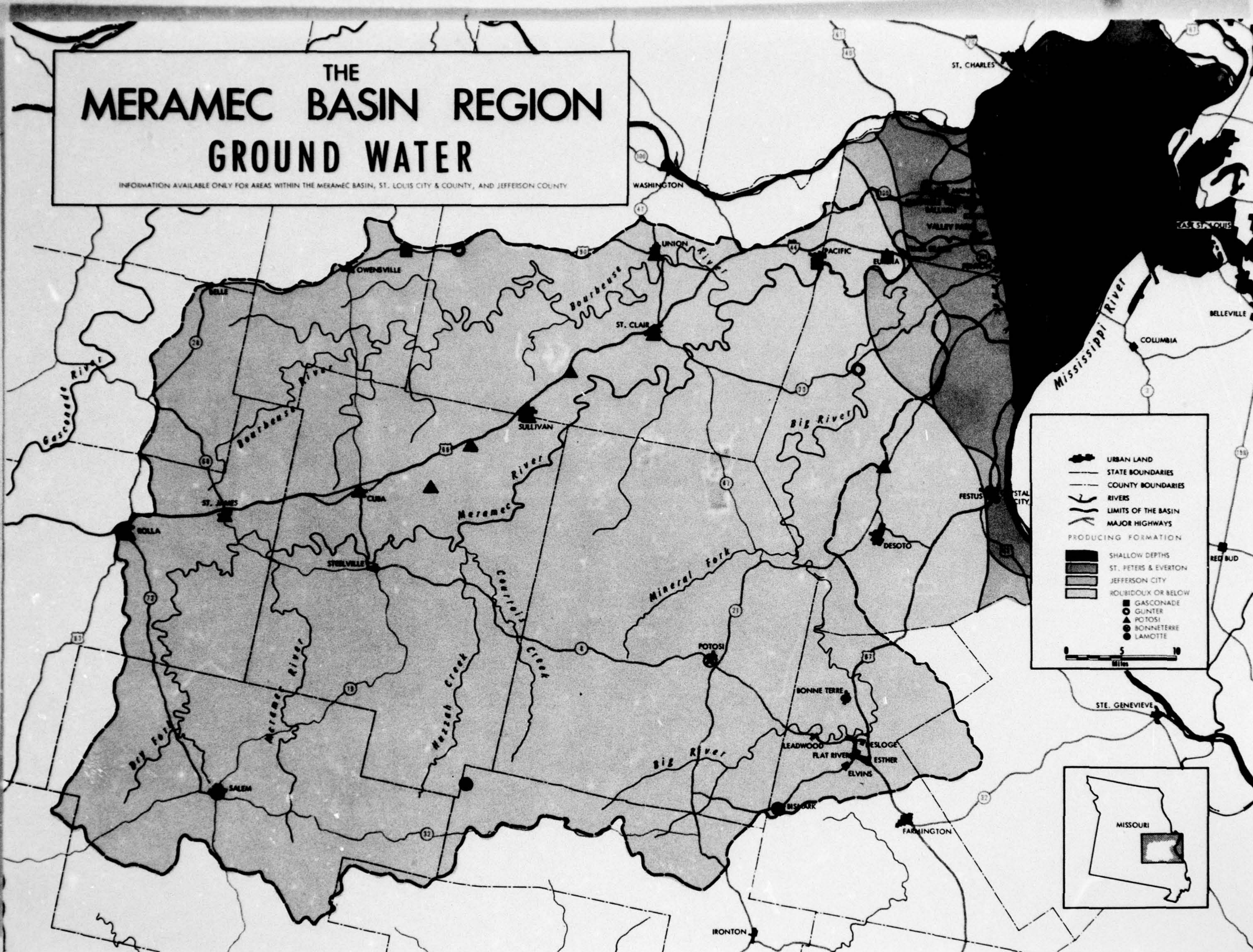
NAME	COUNTY	LOCATION Section	Township	Range	TOTAL DEPTH (feet)	PRODUCTION (gallons per minute)
Potosi formation						
Bourbon (2)	Crawford	34	40N	3W	501	73
Cuba (2)	Crawford	31	39N	4W	1005	233
Salvation Army (Blue Spring)	Crawford	2	39N	3W	550	?
Presbyterian Church	Crawford	18	37N	5W	500	56
Steelville(2)	Crawford	33	38N	4W	535	?
Steelville(2A)	Crawford	34	38N	4W	660	287
U.S.C.C.C.F.13 (No.1)	Washington	17	37N	1W	501	35
St. James (2A)	Phelps	20	38N	6W	1100	360
Rolla (1)	Phelps	11	37N	8W	930	200
Rolla (6)	Phelps	11	37N	8W	1150	580
Rolla (8)	Phelps	11	37N	8W	1125	550
Rolla (4)	Phelps	1	37N	8W	1175	300
Rolla (7)	Phelps	3	37N	8W	1215	585
Rolla (5)	Phelps	1	37N	8W	1078	540
Rolla (Missouri School of Mines, 2B)	Phelps	2	37N	8W	1151	328
Owensville (1)	Gasconade	32	42N	5W	908	200
Owensville (2)	Gasconade	29	42N	5W	962	79
Owensville (3)	Gasconade	28	42N	5W	1000	?
Salem (1)	Dent	13	34N	6W	710	93 ?
Indian Trail State Park (2)	Dent	34	35N	4W	455	25
Union	Franklin		43N	1W	1000	349
St. Clair (4)	Franklin	25	42N	1W	838	36
St. Clair (3A)	Franklin	36	42N	1W	800	80
Meramec State Park (1)	Franklin	18	40N	1W	605	25
Hillsboro (2)	Jefferson	3	40N	4E	1310	100
Bonne Terre formation						
Ironton (6)	Iron	32	34N	4E	300	36
Ironton (4)	Iron	32	34N	4E	424	46
Ironton (1)	Iron	32	34N	4E	293	70
Ironton (2)	Iron	32	34N	4E	467	18

MERAMEC RIVER BASIN

CROSS SECTION THROUGH WELLS — ROLLA TO MAPLEWOOD



STATE OF MISSOURI
DEPARTMENT OF BUSINESS AND ADMINISTRATION
DIVISION OF
GEOLOGICAL SURVEY AND WATER RESOURCES
ROLLA, MISSOURI


THE
MERAMEC BASIN REGION
GROUND WATER
INFORMATION AVAILABLE ONLY FOR AREAS WITHIN THE MERAMEC BASIN, ST. LOUIS CITY & COUNTY, AND JEFFERSON COUNTY
URBAN LAND
STATE BOUNDARIES
COUNTY BOUNDARIES
RIVERS
LIMITS OF THE BASIN
MAJOR HIGHWAYS
PRODUCING FORMATION
SHALLOW DEPTHS
ST. PETERS & EVERTON
JEFFERSON CITY
ROUBIDOUX OR BELOW
GASCONADE
GUNTER
POTOSI
BONNETERRE
LAMOTTE
0 5 10
Miles
MISSOURI
ST. CHARLES
WASHINGTON
UNION
PACIFIC
EUREKA
OWENSVILLE
BELLE
ST. CLAIR
SULLIVAN
CUBA
ST. JAMES
ROLLA
STEELVILLE
SALEM
FESTUS
DESOTO
POTOSI
BONNE TERRE
LEADWOOD
DESLOGE
FLAT RIVER
ESTHER
ELVINS
BISMARK
FARMINGTON
IRONTON
STE. GENEVIEVE
RED BUD
COLUMBIA
BELLEVILLE
Mississippi River
Gasconade River
Bourbeuse River
Meramec River
Big River
Mineral Fork
Courtois Creek
Huzzah Creek
Dry Fork

THE MERAMEC BASIN

Volume III
Water Needs and Problems

Chapter 4
WASTE DISPOSAL AND WATER QUALITY

Meramec Basin Research Project
Washington University
St. Louis, Missouri
December 1961

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Chapter 4

WASTE DISPOSAL AND WATER QUALITY[1]

Summary

Based on limited data, present water quality problems in most of the Meramec Basin appear to be small, and are generally limited to the lower basin area. More complete surveys are required, however, for a definitive assessment of water quality in the Meramec Basin.

About a dozen cities do not have sewage collection systems. However, all of the basin cities having sewerage systems provide secondary sewage treatment except Flat River (primary treatment only) and Valley Park (no treatment).

Potential problem areas, however, exist in the lower basin because of towns and concentrations of clubhouses along the streams. Sanitary water quality is a problem in the reach from Valley Park to the mouth. Available evidence indicates that sanitary water quality has deteriorated in this reach during the past 15 years. Turbidity in the reach between Pacific and the mouth is high enough to conflict with recreational use. Gravel dredging contributes to turbidity problems in this section.

Mining wastes are generally not now a problem, and under proper management can be controlled in the future. Some industrial pollution does occur, particularly at Valley Park. If pulp and paper manufacturing is established in Missouri, it will most likely not be in the Meramec Basin, and therefore will not present any water quality problems in the basin.

No relationship could be found in the Meramec between streamflow and water quality, or between water quality and treatment costs. Therefore, no benefits to water quality from increasing streamflow have been included in the economic analysis of proposed water resource systems, although at a later date, under changed conditions and increasing population, detailed surveys might indicate that increased dilution in certain reaches could be desirable.

Introduction

Contamination can be defined as the introduction into the water of microorganisms, chemicals, and wastes including sewage, which render water unfit for desired uses without corrective treatment. Pollution is generally synonymous with contamination in

Missouri law,[2] although it tends to be slightly more restrictive in some other states.

To what extent is water pollution a problem in the Meramec Basin? What is the present condition of the water resources in the basin with respect to water quality? Generally, water quality in the Meramec Basin appears to be relatively good, or at least adequate, except in the lower reaches of the Big and Meramec rivers. However, there is a paucity of data available on water quality with respect to both surface and ground water. Continuous sampling of surface water at the present time is undertaken at only one place in the basin -- the intake of the St. Louis County Water Company at Fenton. The lack of sampling exists with respect to physical quality characteristics, chemical quality characteristics, and bacteriological and sanitary quality characteristics of water. Since the 1943 survey by the Missouri State Board of Health, there has been no sampling along any reaches of the rivers in the basin. Therefore, a quantitative and adequate analysis of the water quality situation in the basin is impossible at the present time

Sources of Pollution in the Meramec Basin

Based on the relatively small increase in population and industrial development in the Meramec Basin since the general surveys in the early 1940's, the water quality situation appears to have changed little except in the lower portion of the basin, roughly from Pacific to the mouth of the Meramec River. According to the 1943 report[3] "no pollution" existed in the basin at the time of the study. However, even then, there was some potential pollution in areas along the streams in the basin where cabins, clubhouses and recreational facilities were heavily concentrated. Industrial development in the basin has changed little in the intervening period so that new industrial wastes are not a problem, again with the possible exception of the lower river, from Valley Park to the mouth.

Based on data compiled in previous reports, the map shown in Figure 1 was developed. This map is a generalized one which depicts the rough order of magnitude of present waste discharges, primarily domestic and municipal, along the lower portions of the three major streams in the Meramec Basin. The waste discharges are

WASTE DISCHARGES ALONG MAJOR STREAMS IN THE MERAMEC BASIN, 1961

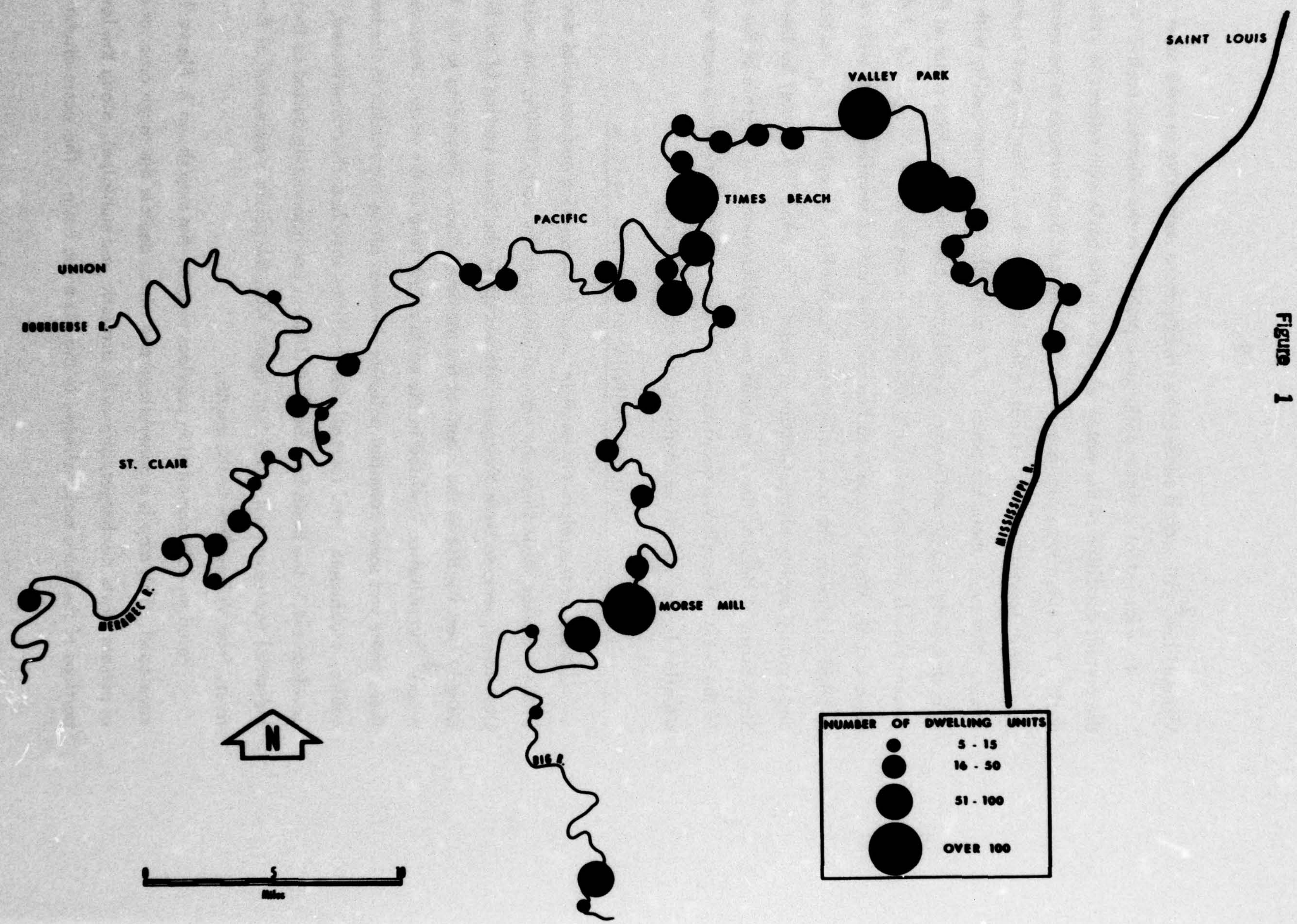


Figure 1

not computed directly on the basis of population equivalents, volume of discharge, or any other similar criteria. Rather, the general magnitude of such discharges is expressed simply in terms of the estimated number of dwelling units contributing essentially untreated wastes. The sources of waste discharges shown are basically of two kinds: (1) concentrations of cabins and houses along the streams (see Figure 1, Volume II, Chapter 4), and (2) urban concentrations such as Times Beach, Valley Park, and Morse Mill. Data on the concentration of cabins and clubhouses were obtained from maps in the files of the firm of Horner & Shifrin, from a map of clubhouses published in the 1943 pollution report of the Missouri State Board of Health[4], and from compilations of the Missouri Water Pollution Board.

Although the map (Figure 1) does not provide specific quantitative estimates of the volume and strength of waste discharges into the major streams in the basin, it does indicate the general nature of the pollution problem in the basin. It suggests the need for a detailed survey along the major streams to identify specific sources of waste discharges, particularly with reference to present and prospective recreation areas. Table 1 appended to the end of this chapter indicates the status of municipal sewage disposal facilities in the Meramec Basin as of November 23, 1960.

Water Quality in the Lower Meramec Basin

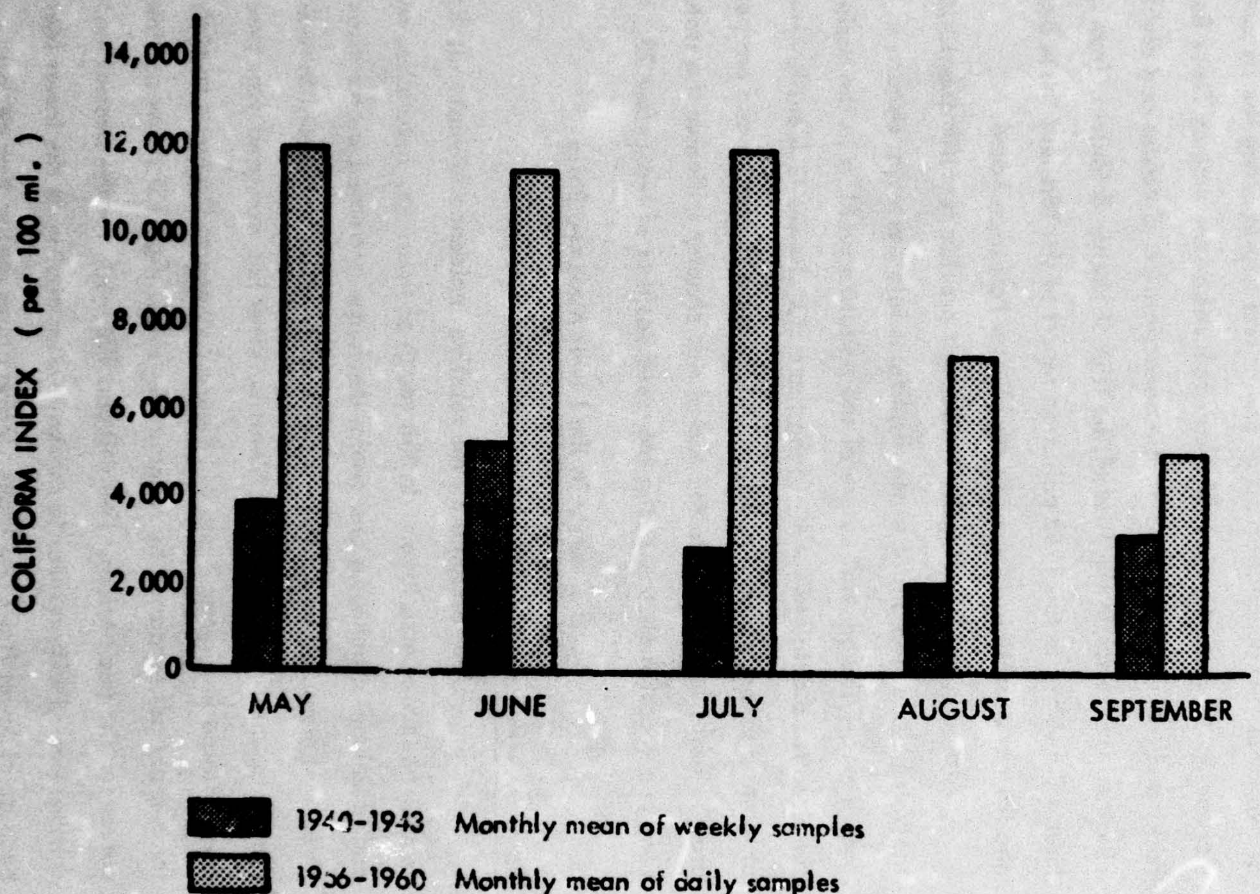
Sanitary water quality trends

As indicated in Figure 1, the relative incidence of waste discharges is greatest in the lower Meramec River. In this reach of the river, industries, municipalities, and individual clubhouses and cabins discharge untreated wastes directly into the river. As measured by sanitary water quality utilizing the coliform index, it appears that water quality in the lower Meramec River has worsened over time. This is demonstrated in Figures 2 and 3. Figure 2 compares the mean monthly coliform index for two periods separated by roughly 15 years. Figure 3 shows coliform index duration curves for the two periods, 1940-43 and 1956-60, for the summer months, the most critical period with respect to sanitary water quality in the lower Meramec River, because of lower flows and higher temperatures during that period.

Figure 2

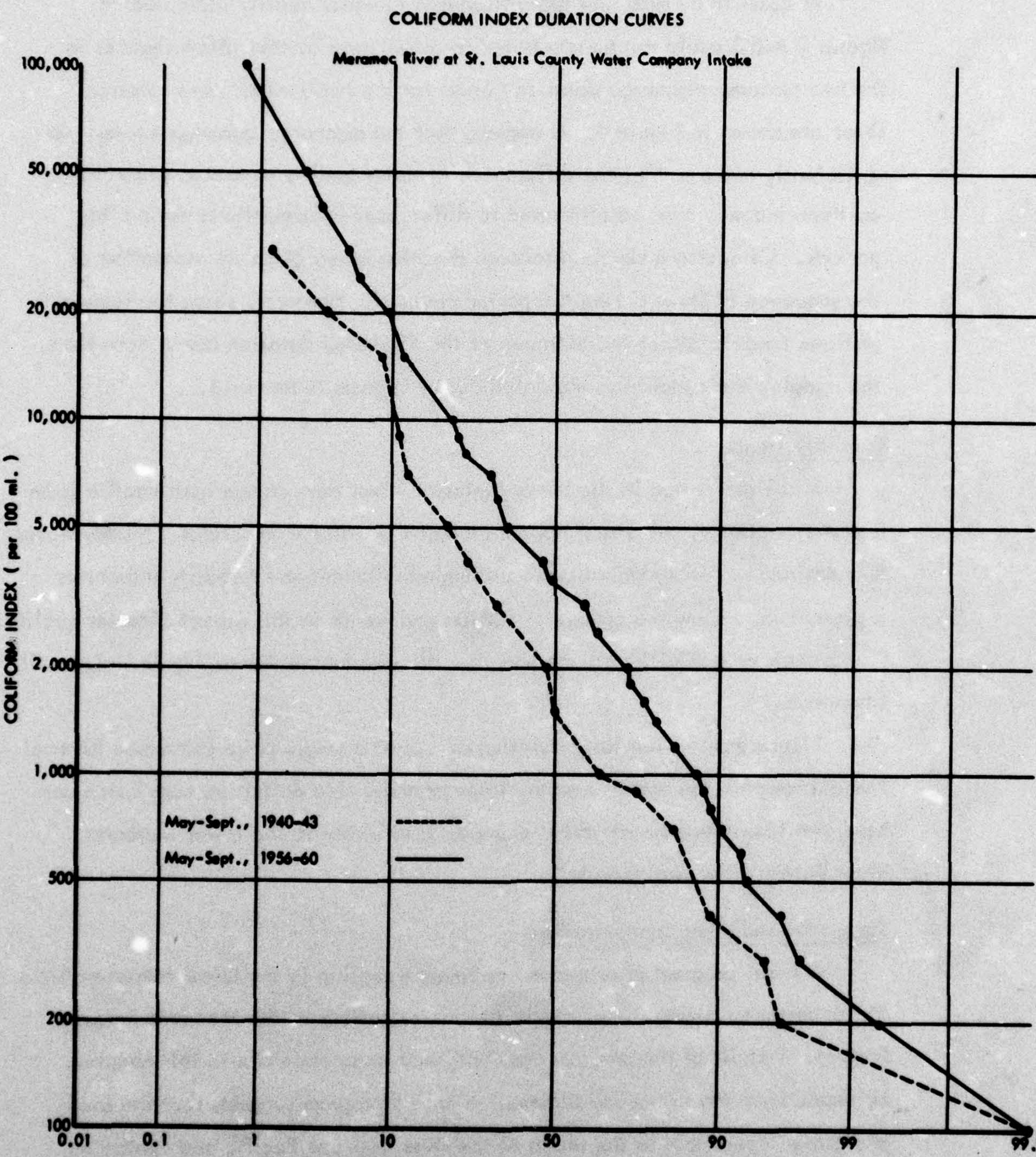
COMPARISON OF COLIFORM INDEX (1940 - 43 and 1956 - 60)

Meramec River at Fenton



Source: Data from St. Louis County Water Company. Samples taken at Company intake, 1956-60; and at approximately same location, 1940-43 during investigations prior to construction of Company plant.

Figure 3


COLIFORM INDEX DURATION CURVES
Meramec River at St. Louis County Water Company Intake
100,000
50,000
20,000
10,000
5,000
2,000
1,000
500
200
100
0.01
0.1
1
10
50
90
99
99.9
COLIFORM INDEX (per 100 ml.)
PERCENT OF TIME INDICATED COLIFORM INDEX WAS EQUALED OR EXCEEDED
May-Sept., 1940-43
May-Sept., 1956-60

In order to be sure that the differences in water quality indicated on Figures 2 and 3 could not be attributed to differences in streamflow regimes in the two periods, discharge duration curves for the two periods were plotted. These are shown in Figure 4. It appears that the discharge duration curves are sufficiently alike so that the differences in water quality as measured by the coliform index cannot be attributed to differences in streamflows during the periods. Of course a simple discharge duration curve gives no indication of the sequence of flows during the period covered. However, since the sequence of flows tends to affect the extremes of the discharge duration curve more than the middle, the conclusion indicated above appears to be valid.

Turbidity trends

Since recreation in the lower Meramec River downstream from Pacific is an important activity, the visual appearance of the water is important. Muddy water is undesirable. An examination of suspended sediment and turbidity indicators is presented to show the present condition and trends in this aspect of water quality. (The effects of turbidity on recreation are discussed more thoroughly in Volume III, Chapter 5.)

Figure 5 shows turbidity duration curves at a single point (Meramec River at Fenton) for both the earlier and the later periods. No definitive conclusion can be drawn from these curves about changes in turbidity in the lower Meramec River between the two periods.[5]

Suspended sediment concentrations

A small program of suspended sediment sampling in the lower Meramec River was undertaken during the course of the investigations of the Meramec Research Project. Details of the program are contained in an appendix to this chapter. Evidence from the suspended sediment sampling program suggests that the sand and gravel operations in the reach of the river between Pacific and Fenton do materially affect suspended sediment concentrations in the river during low flow periods. The absolute effect on sediment concentration is relatively small, an

Figure 4

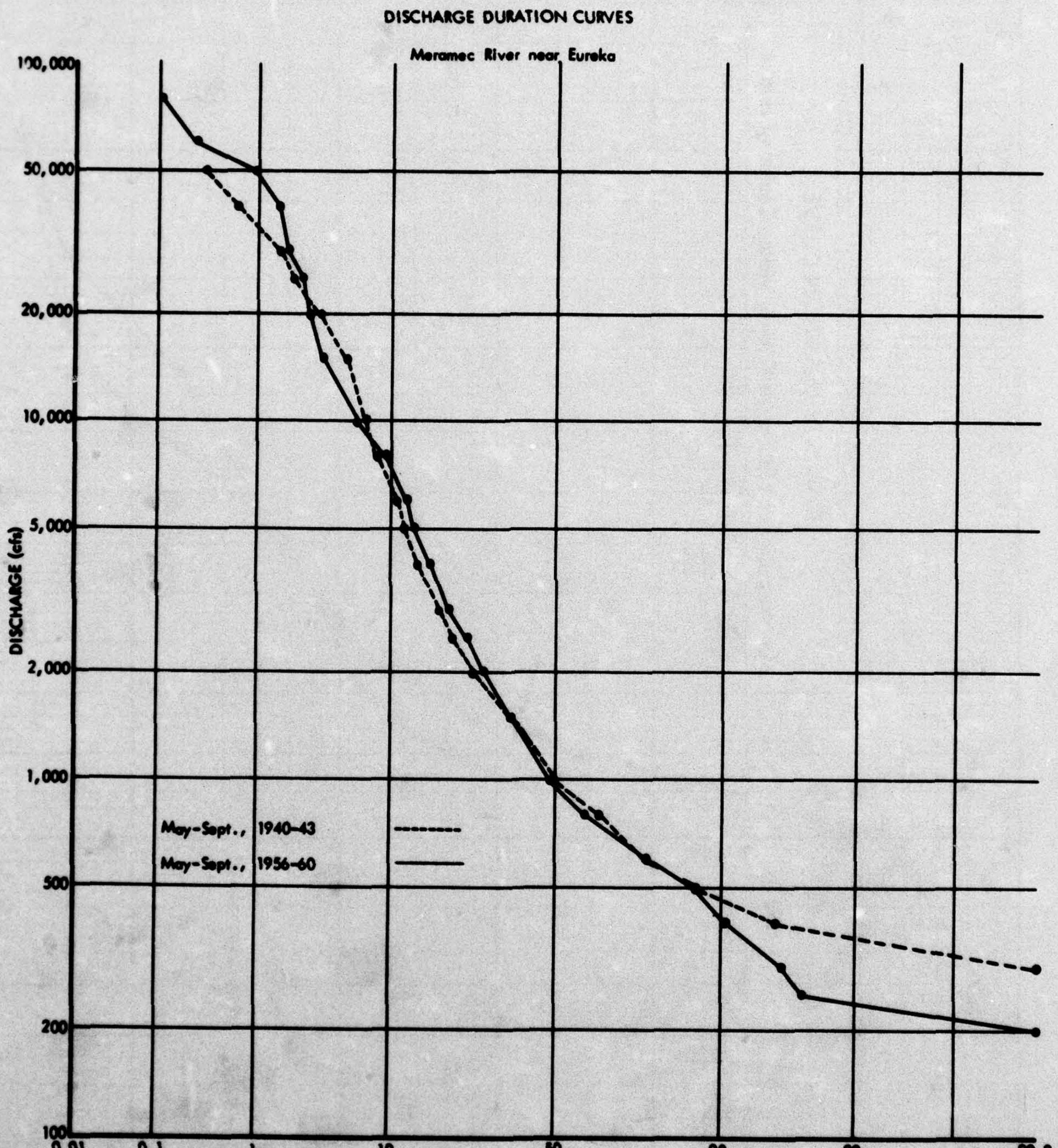
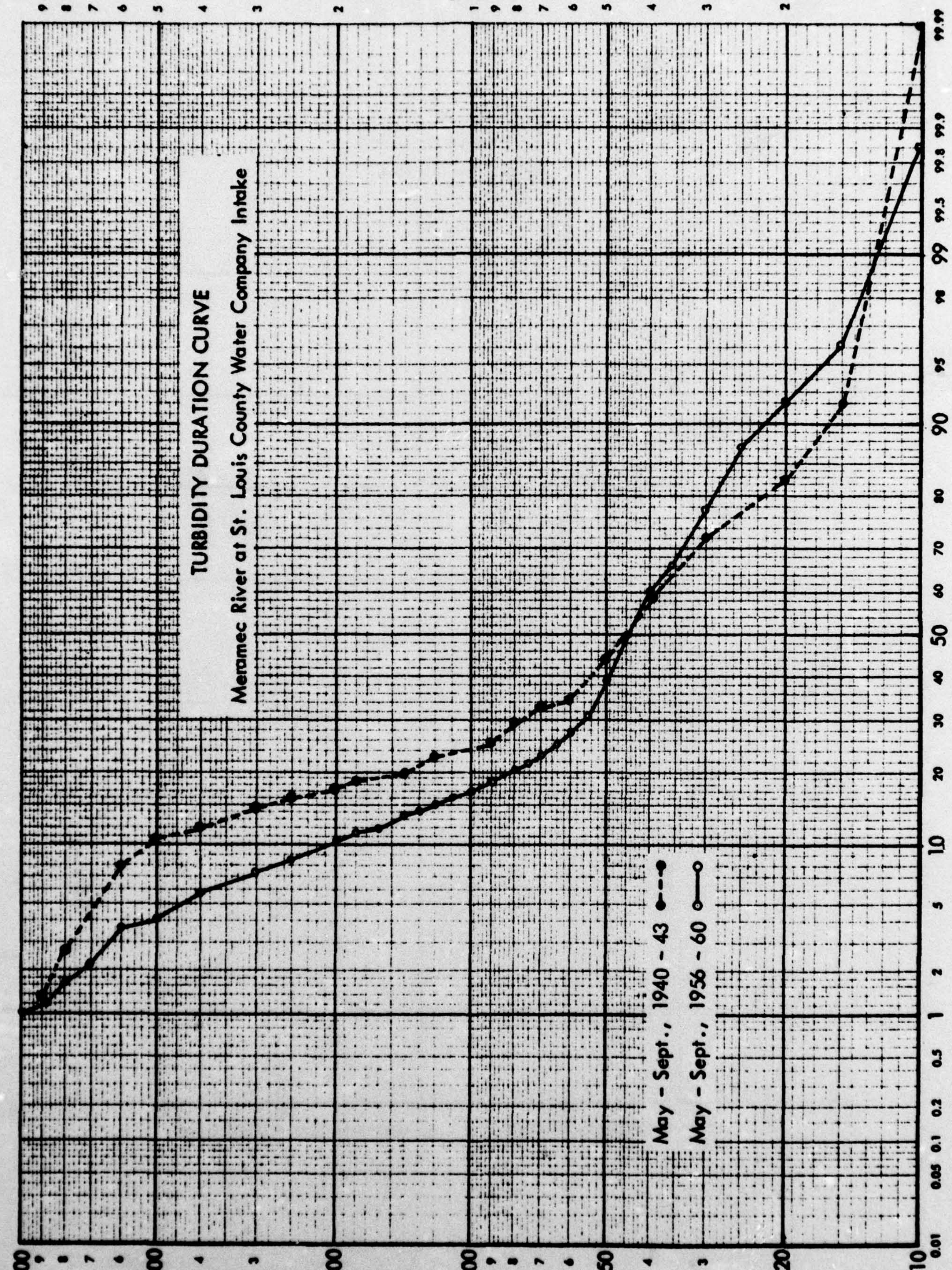

DISCHARGE DURATION CURVES
Meramec River near Eureka
100,000
50,000
20,000
10,000
5,000
2,000
1,000
500
200
100
DISCHARGE (cfs)
0.01
0.1
1
10
50
90
99
99.9
PERCENT OF TIME INDICATED DISCHARGE WAS EQUALED OR EXCEEDED
May-Sept., 1940-43
May-Sept., 1956-60

Figure 5



TURBIDITY DURATION CURVE
Meramec River at St. Louis County Water Company Intake
May - Sept., 1940 - 43
May - Sept., 1956 - 60
TURBIDITY (ppm)
PERCENT OF TIME INDICATED TURBIDITY WAS EQUALED OR EXCEEDED
1,000
500
200
100
50
20
10
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
99.9
99.99

the order of 30-40 parts per million. However, even this small increase in suspended sediment concentration may be important from the standpoint of recreation.

Effect of Increases in Streamflow

In conjunction with efforts to estimate benefits which might accrue to any reservoirs constructed in the Meramec Basin from improvement in water quality, extensive analyses of the relations between water quality and discharge and between water quality and chemical treatment costs were undertaken. Since the lower Meramec River is the only area in which significant withdrawals are made from surface water to meet municipal and industrial needs, it was tentatively hypothesized that improvement in water quality might reduce chemical treatment costs. Therefore an attempt was made first, to relate water quality and discharge, and second, to relate various water quality indices to chemical treatment costs.

Relationship between water quality and discharge

Figures 6 through 13 show the attempts to relate various water quality indices to discharge. As is evident from the scatter diagrams in Figures 6, 7, and 8, definitive relationships between turbidity, alkalinity, hardness, respectively, and discharge can be developed. In the case of the former, increased turbidity accompanies increased streamflows; whereas alkalinity and hardness both decrease with increases in streamflows. However, the scatter diagrams in Figures 9 through 13 suggest that little definitive relationship between coliform index and discharge and between agar count and discharge can be developed. Further evidence of the difficulty of obtaining significant relationships between these two indices of sanitary quality and discharge was provided by correlation analysis. The correlation coefficient between mean daily discharge and coliform index was about +0.5; that between mean monthly discharge and median monthly coliform index was about +0.6; that between daily discharge and total agar count was about +0.5; and that between mean monthly discharge and median monthly agar count was about -0.2.[6]

FIGURE 6

SCATTER DIAGRAM, TURBIDITY AND MEAN DAILY DISCHARGE

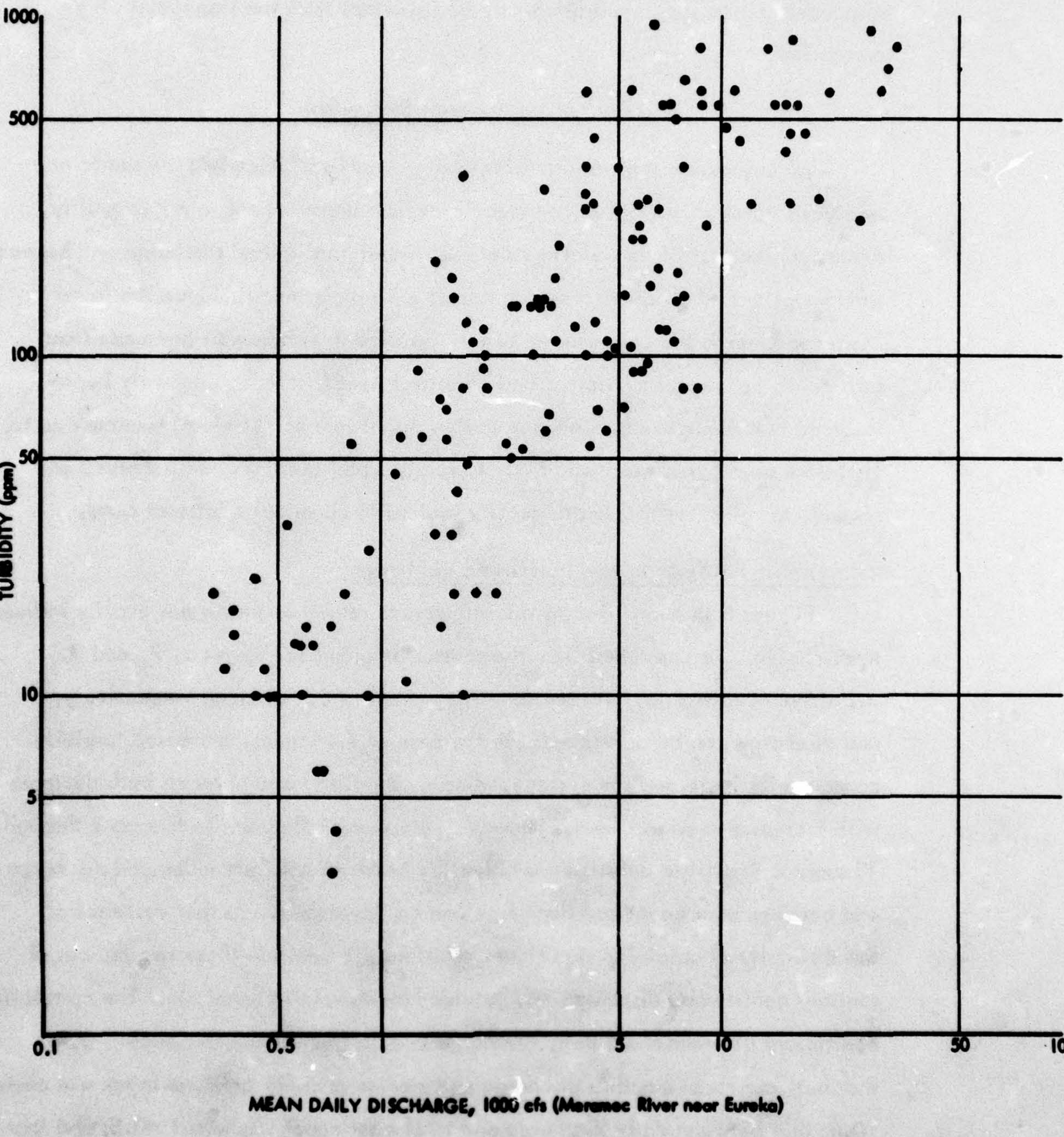


FIGURE 7

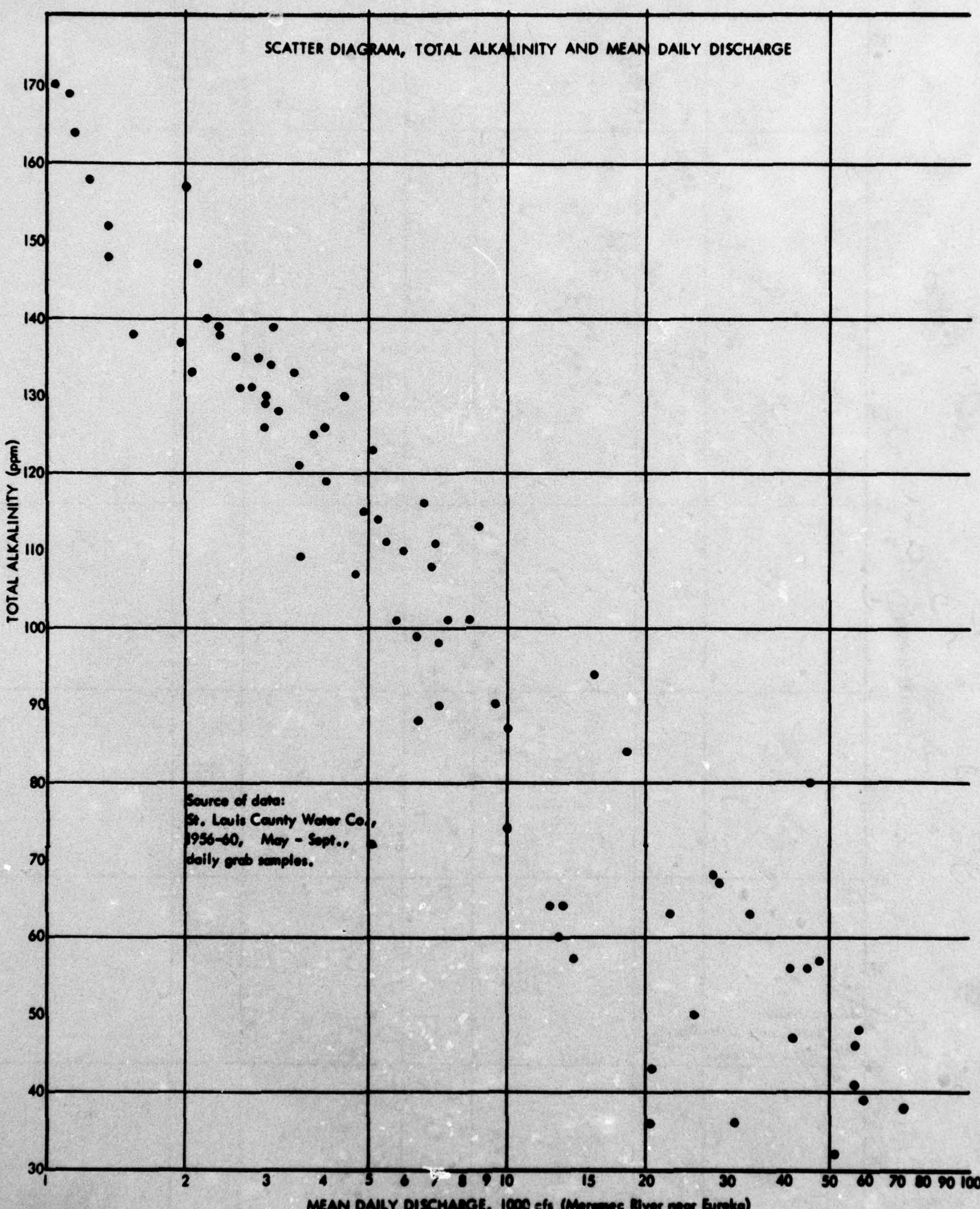

SCATTER DIAGRAM, TOTAL ALKALINITY AND MEAN DAILY DISCHARGE
TOTAL ALKALINITY (ppm)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
1
2
3
4
5
6
7
8
9
10
15
20
30
40
50
60
70
80
90
100
MEAN DAILY DISCHARGE, 1000 cfs (Meramec River near Eureka)
Source of data:
St. Louis County Water Co.,
1956-60, May - Sept.,
daily grab samples.

Figure 8

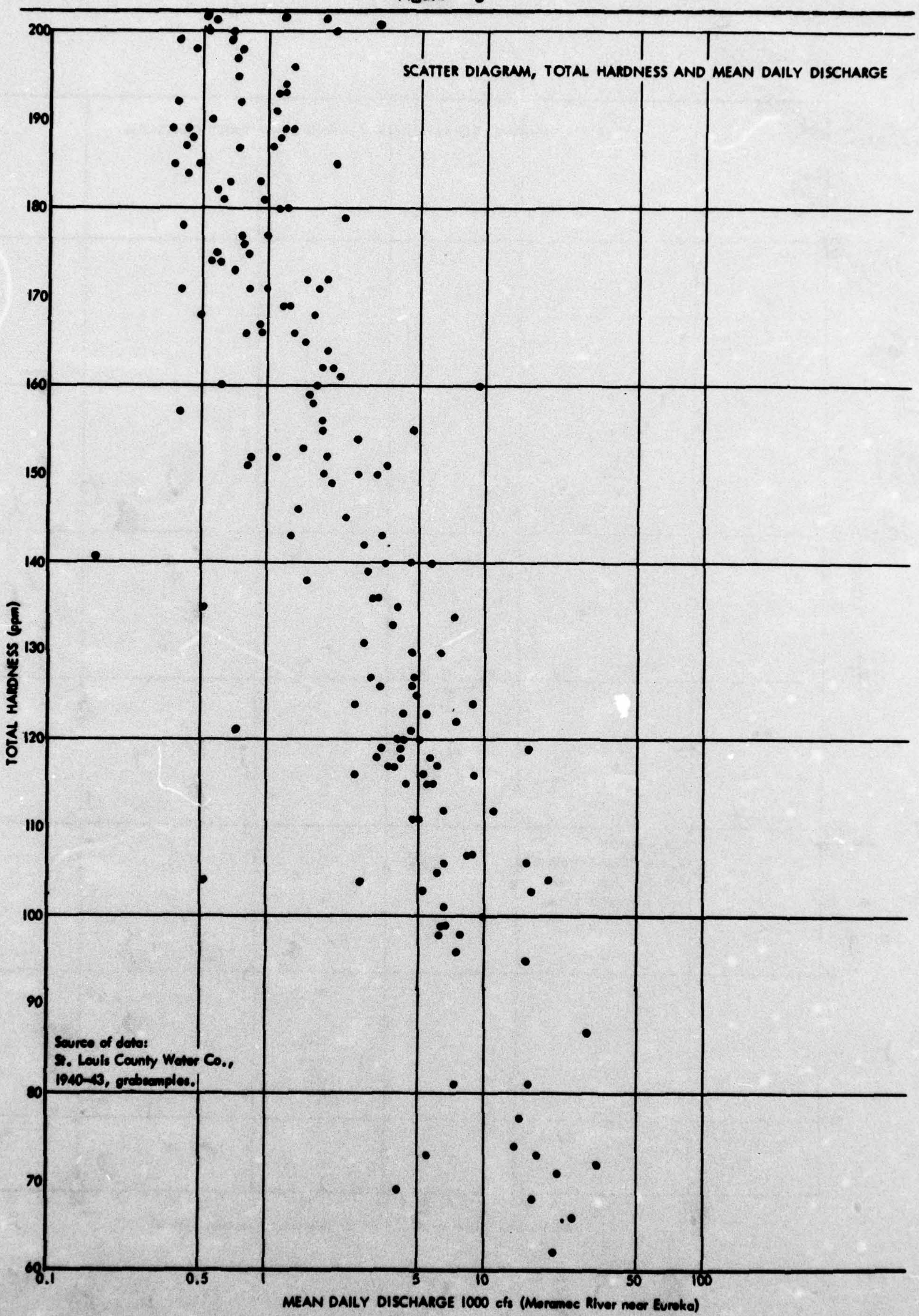

SCATTER DIAGRAM, TOTAL HARDNESS AND MEAN DAILY DISCHARGE
TOTAL HARDNESS (ppm)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
0.1
0.5
1
5
10
50
100
MEAN DAILY DISCHARGE 1000 cfs (Meramec River near Eureka)
Source of data:
St. Louis County Water Co.,
1940-43, grabsamples.

Figure 9

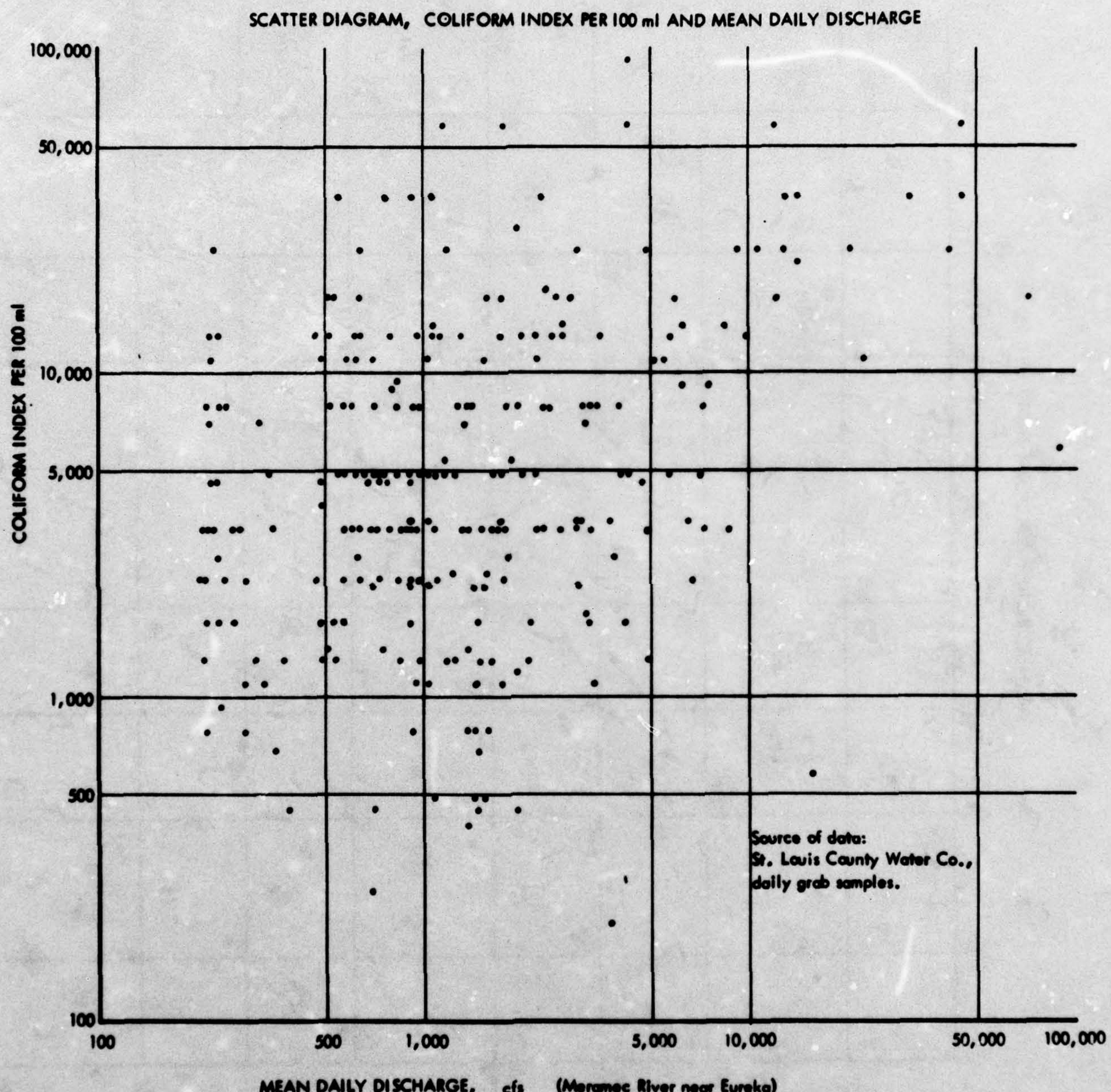

SCATTER DIAGRAM, COLIFORM INDEX PER 100 ml AND MEAN DAILY DISCHARGE
100,000
50,000
10,000
5,000
1,000
500
100
COLIFORM INDEX PER 100 ml
100
500
1,000
5,000
10,000
50,000
100,000
MEAN DAILY DISCHARGE, cfs (Meramec River near Eureka)
Source of data:
St. Louis County Water Co.,
daily grab samples.

FIGURE 10

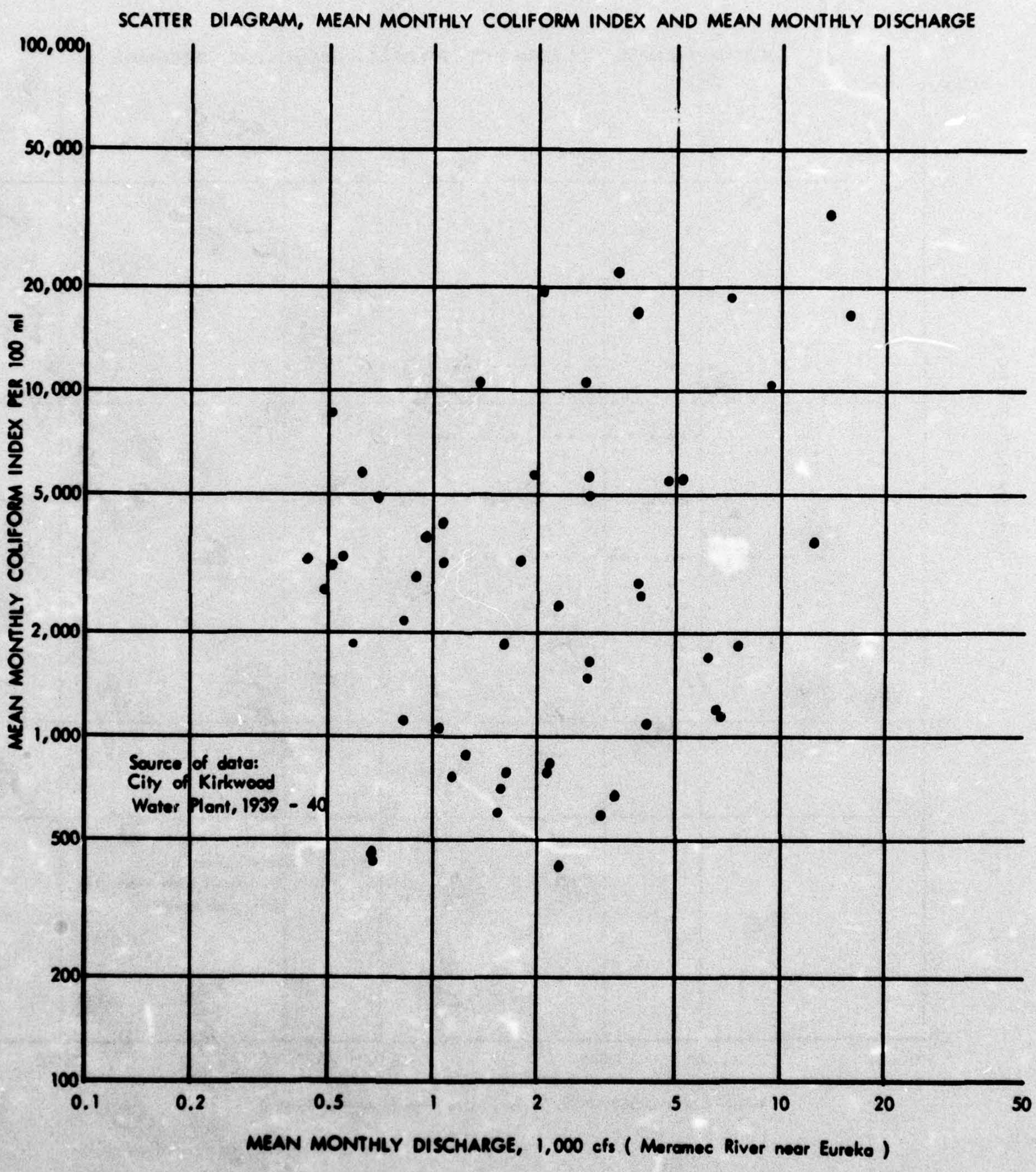

SCATTER DIAGRAM, MEAN MONTHLY COLIFORM INDEX AND MEAN MONTHLY DISCHARGE
MEAN MONTHLY COLIFORM INDEX PER 100 ml
100,000
50,000
20,000
10,000
5,000
2,000
1,000
500
200
100
0.1
0.2
0.5
1
2
5
10
20
50
MEAN MONTHLY DISCHARGE, 1,000 cfs (Meramec River near Eureka)
Source of data:
City of Kirkwood
Water Plant, 1939 - 40

Figure 11

SCATTER DIAGRAM, COLIFORM INDEX AND MEAN MONTHLY DISCHARGE

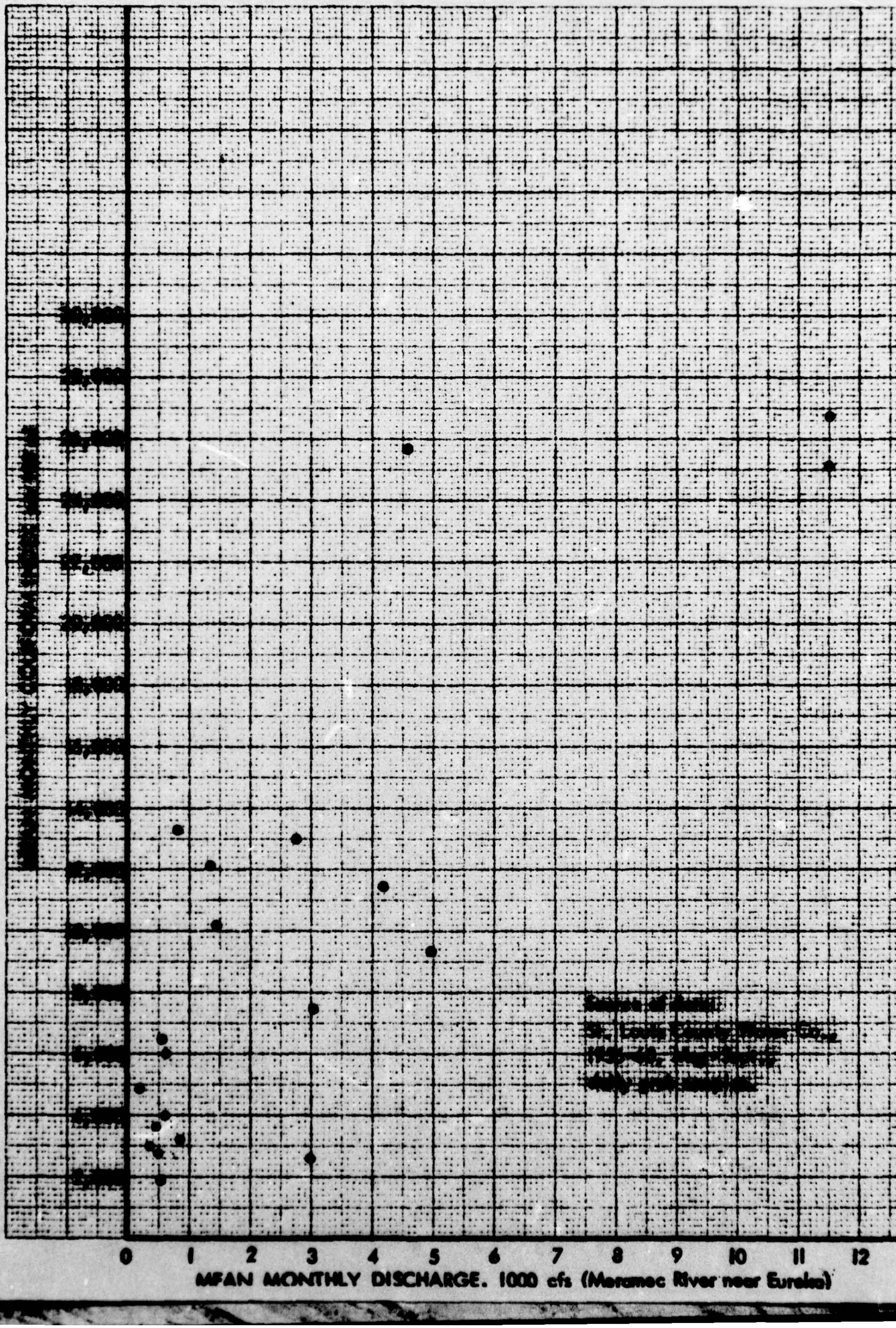


Figure 12

SCATTER DIAGRAM, COLIFORM INDEX AND MEAN MONTHLY DISCHARGE

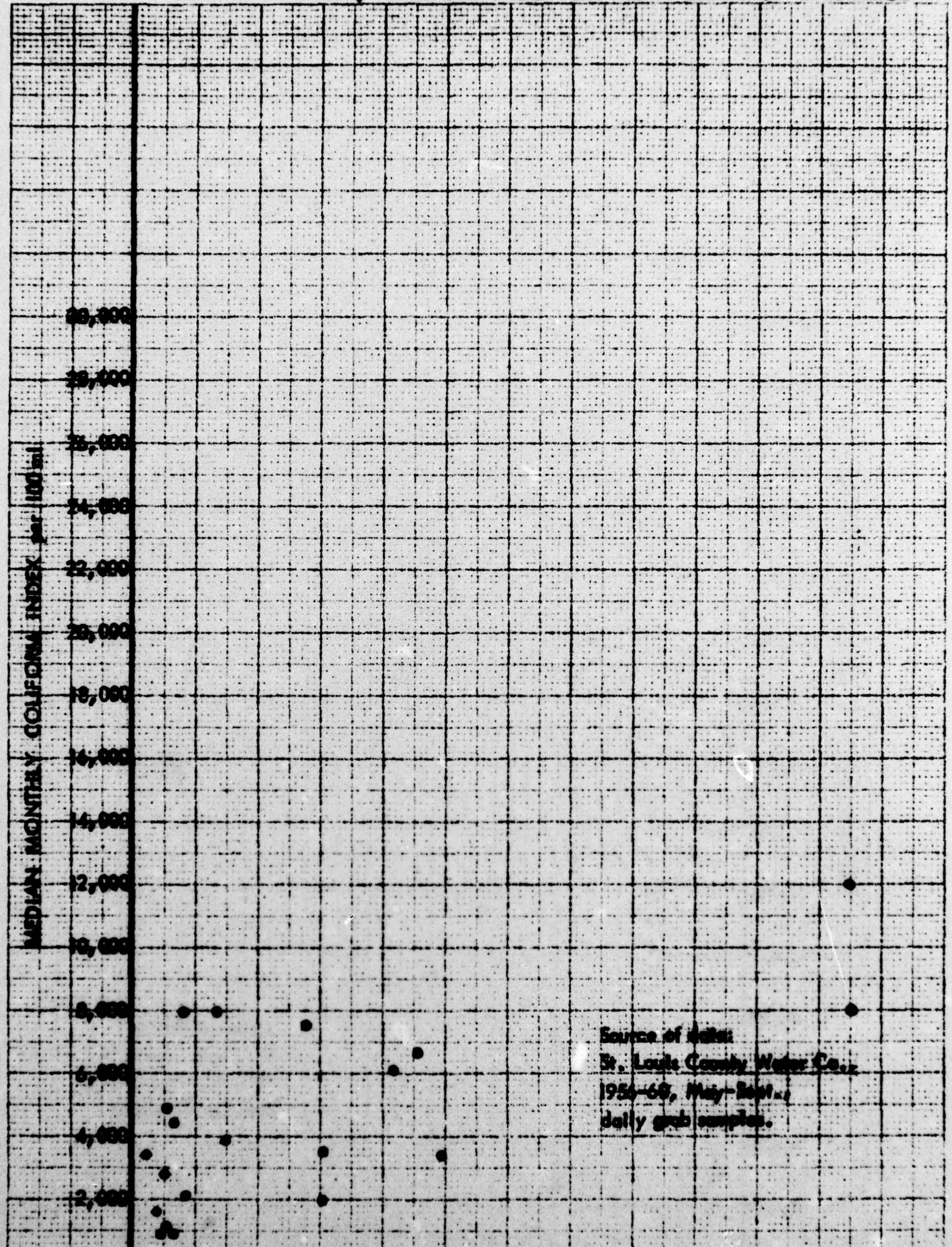
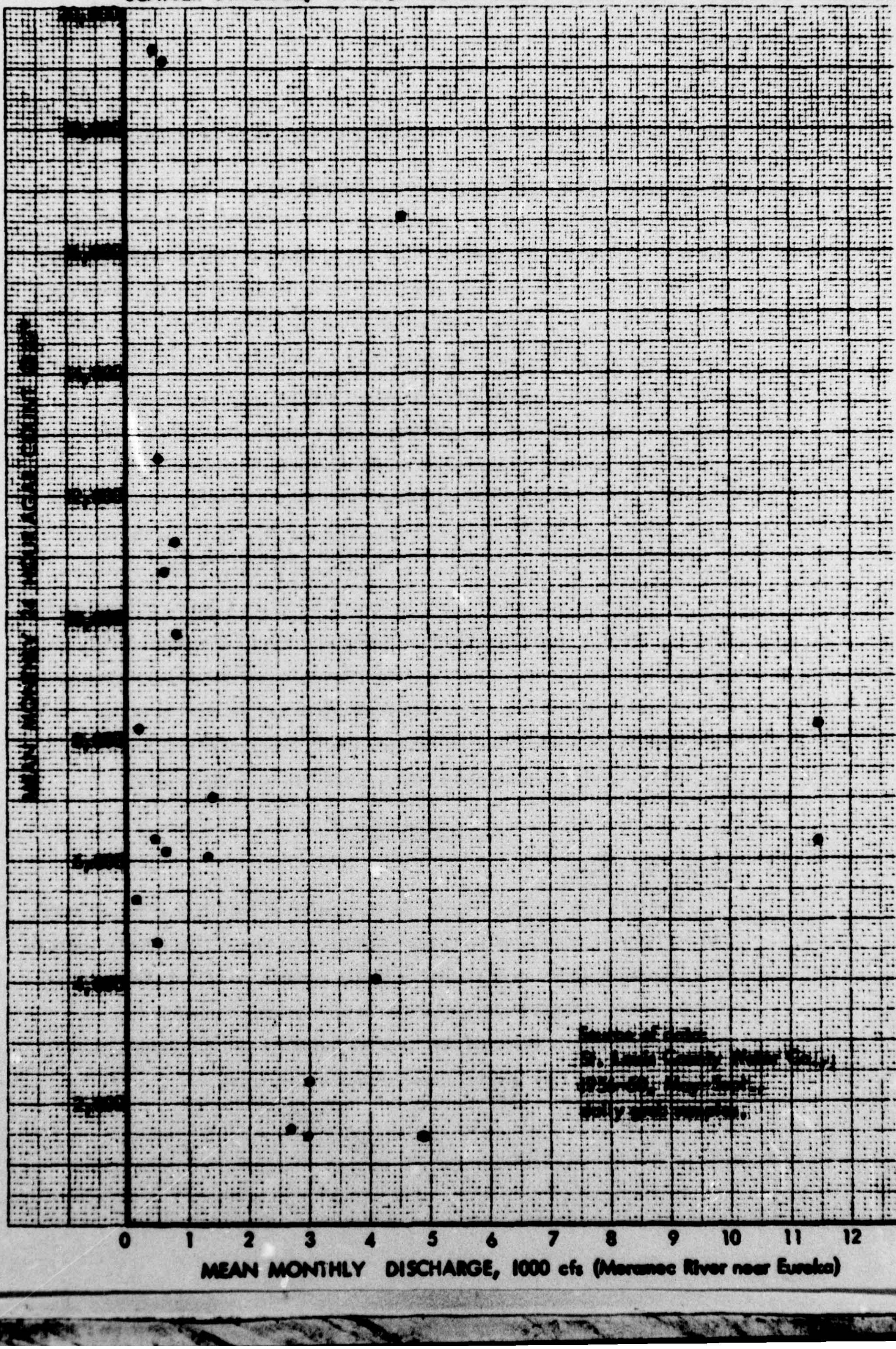


Figure 13

SCATTER DIAGRAM, 24 HOUR AGAR COUNT AND MEAN MONTHLY DISCHAR(



All of these measures indicate a correlation which is not very significant.[6]

Relationship between water quality and treatment costs

An attempt was also made to determine the relationship between chemical treatment costs and water quality. For this purpose multiple regression analysis was utilized with chemical treatment costs as the dependent variable and various water quality indices as the independent variables. Data from the St. Louis County Water Company and from the City of Kirkwood Water Department were used. The results of the multiple regression analyses were inconclusive.[7] A maximum of about 40% of the variation in chemical treatment costs could be explained by variations in the water quality indices. Therefore, in the economic analysis of alternative water development proposals, no monetary benefits were attributed to augmenting low flows or changing the flow regime in the lower Meramec River by reservoir releases in the interest of water quality improvement. The MBRP has not been able to provide the answer to the question of benefits from dilution. Whether a relationship between treatment costs and water quality can be found with more intensive surveys (under future conditions of increased population) is not known. It may be possible to establish such benefits by a study concentrating on the critical low-flow range, and by using other indicators of water quality, such as dissolved oxygen content, in addition to coliform index.

Industrial Wastes

Industry and mining

According to the report by the Missouri Board of Health in 1943, no industrial wastes were considered to be significant at that time.[8] The situation appears to be essentially the same at present, with the possible exception of the vicinity of Valley Park where some industrial wastes are discharged untreated to the Meramec River. It is expected that both the industrial and municipal pollution problems in Valley Park will be corrected in the near future.

The 1943 report indicated that neither lead mining nor tiff mining materially affected water quality downstream from such operations. Similarly, iron mining operations present no threat to water quality in the basin as long as large or multiple tailing ponds are utilized. However, occasional problems exist when impounding dams are built too low or too unstable to withstand water pressure during heavy rainfall.[9]

Pulp or paper manufacturing

It has been proposed that, because there is a considerable amount of wood volume available in and near the Meramec Basin, a pulp or paper manufacturing plant be established within the Meramec Basin. However, an analysis of the forest industry in the basin (See Volume II, Chapter 3.), indicates that a more likely location for a paper or pulp mill is in the area south of the Meramec Basin, closer to the center of the available timber resource. Louis Warrick of the Public Health Service has suggested that the logical location for any pulp mill in the area is outside of the Meramec Basin to the south.[10] It should be noted, however, despite much publicity to the contrary, that contamination of water quality is not necessarily a concomitant of a paper or pulp mill. Technological processes are available such that the potential pollution effects of such operations can be rendered negligible.[11] Admittedly, the installation of equipment to minimize pollution aspects requires considerable investment. However, the point is that reducing pollution from such operations is possible. In some cases it has been found that measures to reduce pollution from pulp and paper operations have resulted in new processing techniques enabling the recovery of chemicals or the development of by-products.[12]

Conclusions

1. Water quality in the Meramec Basin appears to be adequate for all uses except in areas where concentrations of clubhouses and cabins along the rivers result in degradation of the sanitary quality immediately downstream therefrom,

and in the lower Meramec River area from about Pacific to the mouth where significant quantities of untreated municipal and industrial wastes are discharged into the stream.

2. In the lower Meramec River, where significant quantities of water are withdrawn for municipal and industrial purposes, backwater from the Mississippi River appears to be no problem with respect to such withdrawals. The only apparent affect during backwater periods is an increase in colloidal matter.[13]

3. Based on the analyses made in the course of the investigations of the Meramec Basin Research Project, there is no conclusive evidence that increasing low flows in the lower Meramec River would result in monetary benefits from improvement in water quality. Of the three classes of possible benefits from dilution -- reduction in sewage and waste treatment costs, reduction in municipal or industrial water treatment costs, and benefits from increased utilization of the river for recreational and aesthetic purposes -- the latter is least susceptible to economic analysis, but might be of considerable importance in the Meramec. The analyses of water quality and water treatment costs indicate that only a small part of the water treatment costs can be attributed to water quality deficiencies. The same analyses indicate that it is not likely to be possible to reduce the level of treatment in the proposed Metropolitan Sewer District system serving St. Louis County because of increased flows which might be made available from reservoirs in the Meramec Basin. Secondary treatment of waste discharges would be required even with increased flows. Further study would be desirable to determine whether changing conditions as population increases will modify these conclusions.

4. There is a definite need for establishing continuous sampling of water quality in the basin, particularly of surface water in the lower Meramec and Big rivers. Similarly, there is a need to make a detailed inventory of the clubhouses, homes, and cabins along these reaches which may discharge untreated sewage into the river. Since recreation is important in these reaches, a continuous monitoring of sanitary water quality in the area is essential, at least during the major recreation season.

5. If the surface waters of the lower Meramec Basin are to be used for recreation, measures should be taken to prevent upstream sand and gravel operations from degrading water quality in the rivers by increasing turbidity. Methods of operation of most sand and gravel companies do not appear to adversely affect water quality.[14] All companies not using such methods should be required to adopt them.

REFERENCES AND NOTES

1. Appreciation is expressed to Jack K. Smith, Executive Director, Missouri Water Pollution Board, for supplying necessary data and for making many valuable suggestions which have been largely incorporated in this chapter.

2. Missouri Water Pollution Board, Water Pollution Law and Regulations, no date, (chapter 204).

3. Missouri Division of Health, A public health program for the Meramec Basin (Appendix 5 of the Meramec Cooperative Investigation Field Committee Summary Report, 1949), no date, p. 16.

4. State Board of Health of Missouri, Meramec River pollution study, 1943, Figure 4.

5. However, in that part of the curve where the visual effect of turbidity is most in evidence (around 20 ppm., where the transition of "muddy" to "clear" appears to take place) there has been some deterioration. Even this improvement is only on the order of 10% (of the time) and is not very significant. If data were available for earlier periods, greater deterioration in quality might be evident. (See appendix to Volume III, Chapter 5).

6. These measures indicate a slight tendency for sanitary water quality to worsen as flows increase. These results are consistent with those of the 1943 pollution study (op.cit) in which the coliform index at Eureka was found to increase with increasing flows (Table 11, p.15) According to this study "when the accumulated fecal matter from all animals on a watershed is washed into a stream following a period of rainfall of sufficient intensity to produce surface runoff, the concentration of coliform organisms will greatly increase."

7. The results of these analyses are available from the files of the Meramec Basin Research Project.

8. State Board of Health of Missouri, op.cit., p. 13.

9. See papers by Kenneth J. Weber of the Ozark Ore Company, and P. G. Barnickol of the Missouri Conservation Commission, in selected papers from the air and water pollution conference, November 17, 1958, Engineering Experiment Station Bulletin No. 45, University of Missouri, Columbia, Mo., 1959, p. 10, pp. 17-20.

10. Louis F. Warrick, Solving pollution problems of pulp and paper mills, Proceedings of Sixth Annual Air and Water Pollution Conference (1960), Engineering Experiment Station Bulletin No. 53, University of Missouri, Columbia, Missouri, 1961.

REFERENCES AND NOTES (continued)

11. See California State Water Pollution Control Board, Waste treatment and disposal aspects to development of California's pulp and paper resources, Publication No. 17, 1957.

12. See for example, Water Information Center, Research and Development News, Vol. 2, No. 6, June 1961 in which the following item appeared: "Effective control of pollution caused by spent sulphite liquor is claimed by Nichols Engineering and Research Corporation -- New York, New York -- for a new process which converts the liquor into a dry product for industrial use."

13. Information from J. L. Tuepker of the St. Louis County Water Company.

14. If the method of extraction is from the alluvial deposits of the flood plain rather than from the bed of the river, and if the water used in the washing and sorting operations is not discharged directly into the river, downstream water quality need not be affected.

TABLE 1

STATUS OF MUNICIPAL SEWAGE DISPOSAL, MERAMEC RIVER BASIN
AS OF NOVEMBER 23, 1960

I. COMMUNITIES WITH SEWAGE COLLECTION SYSTEMS

COMMUNITY	1960 POPULATION[a]	DESIGN POPULATION	DEGREE OF EXISTING TREATMENT	NEEDED POLLUTION CONTROL MEASURES
Belle	1,016	2,000	Secondary	None
Bismark	1,237	1,200	Secondary	Addition of final settling
Bland	654	596	Secondary	Final tank (Bonds voted)
Cuba	1,672	1,500	Secondary	None
Ellisville[b]	2,732	-	Secondary	-
Eureka	1,455[c]	972	Secondary	Plant expansion
Flat River	4,515	6,000	Primary	Addition of secondary facilities (Engineering report approved)
Kirkwood #2 Plant	29,421[d]	12,000	Secondary	None
Meramec Mining Co. Pea Ridge	-	478	Secondary	None
Owensville	2,379	4,500	Secondary	None
Pacific	2,795	3,600	Secondary	None
Potosi	2,805	3,500	Secondary	None
Rolla, East Plant	11,132[e]	5,000	Secondary	None
South Plant	-	12,000	Secondary	None
St. Clair	2,711	3,200	Secondary	None
St. James	2,384	3,450	Secondary	None
Salem	3,870	3,800	Secondary	None
Steelville	1,127	2,000	Secondary	None
Sullivan	4,098	4,500	Secondary	None
Union	3,937	7,400	Secondary	None
Valley Park	3,452	4,600	None	New plant (Engineering report approved)
Viburnum	590	650	Secondary	None

TABLE 1

STATUS OF MUNICIPAL SEWAGE DISPOSAL, MERAMEC RIVER BASIN
AS OF NOVEMBER 23, 1960 (continued)

II. COMMUNITIES WITHOUT SEWAGE COLLECTION SYSTEMS

COMMUNITY	1960 POPULATION	REMARKS
Ballwin	5,710	(Engineering report approved for sewer system and secondary treatment)
Bonne Terre	3,219	(Bonds voted for sewer system and secondary treatment)
Bourbon	779	
Des Peres	4,362	
Desloge	2,308	(Bonds voted for sewer system and secondary treatment)
Elvins	1,818	(Engineering report approved for sewer system and secondary treatment)
Esther	1,033	
Fenton	1,059	
Hillsboro	457	
Irondale	335	
Leadwood	1,343	
Manchester	2,021	(Sewer system and secondary treatment under construction)
Times Beach	986	
Winchester	1,299	

[a]U.S. Bureau of Census, Census of Population, 1960, Missouri.

[b]Present discharge of lagoon is to Missouri River drainage basin.

[c]Present population, estimated. Higher than 1960 Census figure because of extensive subdivision development which has occurred since the census was taken.

[d]Kirkwood #1 Plant is tributary to Gravois Creek. In 1950, when the population of Kirkwood was 18,640, about 9,000 persons were tributary to the Kirkwood #2 Plant. Between 50% and 60% of the present population is tributary to this plant.

[e]In 1950 when the population of Rolla within the city limits was 9,354, about 3,950 persons were tributary to the East Plant, about 6,500 persons to the South Plant. No information is available as to present distribution of population served between plants.

Data provided by Jack K. Smith, Executive Secretary, Missouri Water Pollution Board.

TABLE 1: SUMMARY

The total present population of the 20 sewered communities in the Meramec Basin is about 85,000. Not all of the population in any given city with a sewage collection system is necessarily connected to the system. Also, some persons living outside the city limits in a given city may be connected to the city system. Further, not all of the sewage represented by the total population connected is discharged into the Meramec Basin, since some of the communities are located on the drainage basin divide. (Kirkwood is an example.)

All of the communities with sewage collection systems, with the exception of Valley Park, have sewage treatment facilities. For four of these communities -- Bismarck, Bland, Eureka, and Flat River -- the Missouri Pollution Board has indicated that additions or enlargements to the treatment facilities are necessary to handle the present sewage load. If at least 50% of the present population of Kirkwood is assumed to be served by the #2 plant, then, given the relationship between present population and design population of the respective plant facilities, three other communities -- Cuba, Kirkwood,[1] and Salem -- should be giving consideration to expansion of sewage treatment facilities, unless population in those towns were assumed to have reached "saturation". Valley Park, with a combined connected population of about 3,500, discharges sewage directly to the Meramec River without treatment.

The total population of the 14 unsewered communities listed is about 26,000. Several thousand more persons reside in smaller communities in the basin having no sewage collection systems.

Wet industries located in cities with sewer systems are connected to the respective municipal systems, with the exception of at least one industry in Valley Park. Industrial wastes from industries located outside city sewer systems are not believed to be significant, according to the Missouri Water Pollution Board.

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[1] Kirkwood has now, i.e., 1961, completed a sewage lagoon adjacent to the #2 plant. The lagoon will enable adequate treatment of sowage from the present tributary population.

THE MERAMEC BASIN

Volume III

Water Needs and Problems

Chapter 5

RECREATION

Meramec Basin Research Project
Washington University
St. Louis, Missouri
December 1961

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Chapter 5

RECREATION

Recreation in the United States

Trends in demand for recreation

The demand for outdoor recreation has increased at a spectacular rate over the past half-century. At several National Parks attendance has increased 15-30 times between 1920 and 1956.[1] The average rate of growth of attendance at National Parks since 1946 has been slightly less than 10% annually -- National Forests have exhibited a similar rate of growth.[2] Water-based recreation has increased at an even more rapid rate. The rate of gain in attendance during the post-war years at Corps of Engineers' reservoirs has been approximately 28% annually. The rate of growth at TVA reservoirs during the same period has been about 15% annually.[3]

The reasons for this growth are not hard to find. Population increases, coupled with increases in income, leisure, and mobility of the population, are chiefly responsible. Past trends and predicted future trends in these variables, as described by Clawson, are shown in Figure 1. Per capita disposable income has roughly doubled within the past half-century, and is expected to more than double within the next half-century. The average number of hours worked per week has declined from approximately 60 hours to 40 hours since 1900, and will probably decline further to about 30 hours in the year 2000. People will have more free time, much of which will go into recreation. More than 20% of free time goes into outdoor recreation today, and future increases are likely. Mobility has increased

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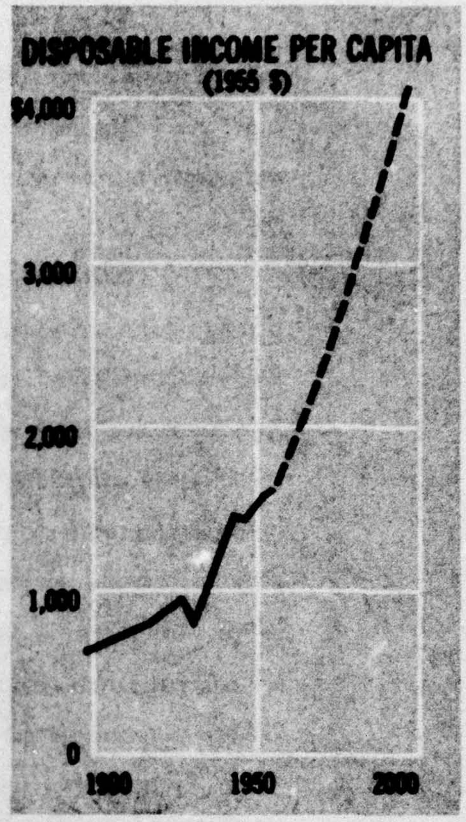
[1] Marion Clawson, The Crisis in Outdoor Recreation, Resources for the Future, Reprint No. 13, 1959, p. 17.

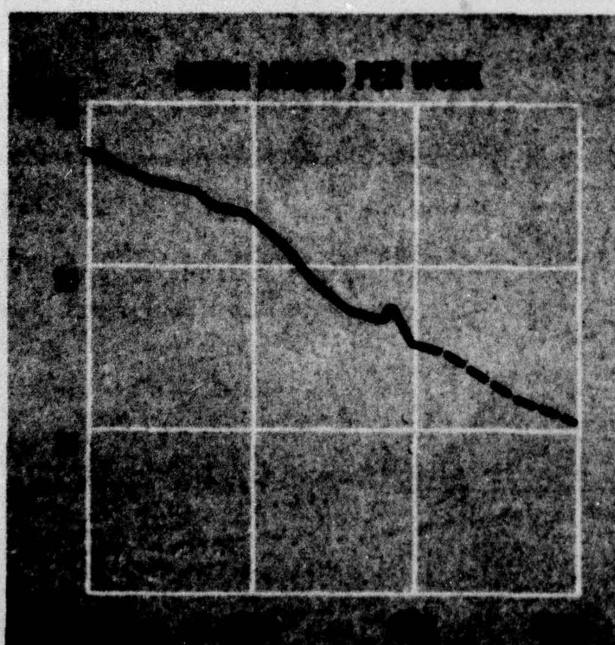
[2] Martion Clawson, Statistics on Outdoor Recreation, Resources for the Future, Washington, 1958, pp. 17-45.

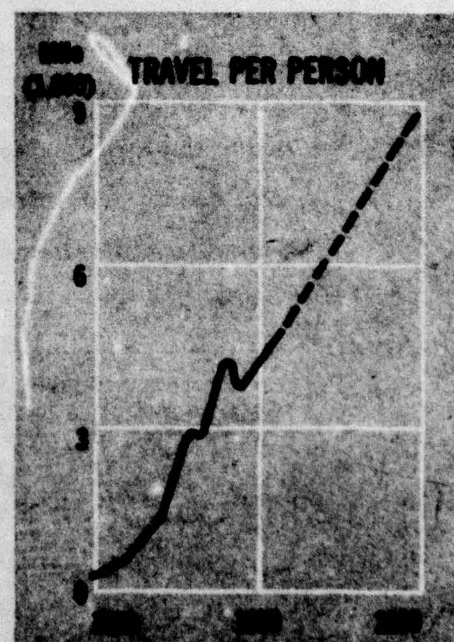
[3] Marion Clawson, Crisis . . . . ., p. 8. Because the Corps of Engineers is constantly adding to the number of reservoirs under its jurisdiction, its rate of growth reflects changes in supply as well as demand characteristics. The TVA statistics are from a relatively fixed number of impoundments and are therefore a better indicator of demand changes.

TRENDS AFFECTING
OUTDOOR RECREATION

From: The Crisis in Outdoor Recreation by Marion Clawson







spectacularly since 1900, and will continue to increase at a somewhat less spectacular rate in the future. (Clawson predicts a doubling in the number of miles traveled per person by the year 2000; Wilbur Smith and Associates predict even greater increases.)[4]

The inclination to participate to a greater degree in outdoor recreation is already quite evident. A survey undertaken by the Outdoor Recreation Resources Review Commission[5] reports that a large number of people would like to engage in a great deal more recreation activity than they do at present. Lack of time is the chief barrier; lack of money is next. As people get more of both, there will be a considerable step-up in the per capita demand. This increase in per capita demand, couple with population increases (predictions are for a doubling of population within the next half-century) will result in very large increases in the demand for outdoor recreation. The ORRRC predicts a threefold increase by the year 2000. Others have predicted even larger increases.

"Most people seeking outdoor recreation want water . . . ."[6] "Water is [therefore] a key factor of supply. It is essential for many forms of recreation; and it adds to the enjoyment of many others."[7]

Supply of outdoor recreation resources

How does the supply of recreation facilities compare with the demand -- now and in the future? The question is not easily answered by an examination of the total available acreage of recreation land and water. A fairly large acreage is available in the United States but "the problem is not one of number of acres but of effective acres -- acres of land and water available to the public and useable

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[4] Marion Clawson, Crisis . . . ., p. 11, and Wilbur Smith and Associates, Future Highways and Urban Growth, New Haven, Conn., 1961, p. 201.

[5] ORRRC, Outdoor Recreation for America, Washington, 1962, p. 31.

[6] ORRRC, p. 4.

[7] ORRRC, p. 69.

for specific types of recreation."[8] ". . . . demand . . . . is concentrated where people are -- near metropolitan areas. . . . This metropolitan population must get most of its recreation in the metropolitan region, and, for all practical purposes, the existance of extensive facilities somewhere else is little compensation for lack of them at home."[9] For example, the thousands of lakes in the northern parts of Minnesota, Wisconsin, and Michigan are of no use to the people of St. Louis or Memphis for one-day or weekend trips. Only those recreation facilities which are located within about 50-100 miles of each city can be used to satisfy this short-period recreation demand (which, in spite of longer vacations, still represents the major portion of time available for recreation). Therefore, for this type of recreation, the overall U. S. statistics have little meaning. To properly assess the situation it is necessary to examine the recreation facilities available within easy driving time from each major center of population. The outlook for the St. Louis area is discussed in the next section.

The importance of distance in influencing the intensity of use of recreation facilities is elaborated in Appendix A. Restated briefly, a study of attendance figures for Corps of Engineer reservoirs shows that of approximately 40 large reservoirs listed, only seven have a very high intensity of use. All seven are located near large metropolitan areas. Moreover, certain small reservoirs located very close to or within metropolitan areas exhibit a phenominal intensity of use. These lakes, only a few hundred acres in size, attracted from 500,000 to 1,500,000 visitor-days in 1960. Clearly, distance from potential users is of considerable importance in assessing the available supply of recreation resources. The importance of this factor is elaborated on in a later section.

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[8] ORRRC., p. 49.

[9] ORRRC., p. 26.

The Demand for Water Recreation in the Meramec Basin

Present recreation situation in the St. Louis area

The present and past recreation situation in the Meramec Basin and St. Louis area are described more fully in Volume II, Chapter 4. A brief summary will be useful here.

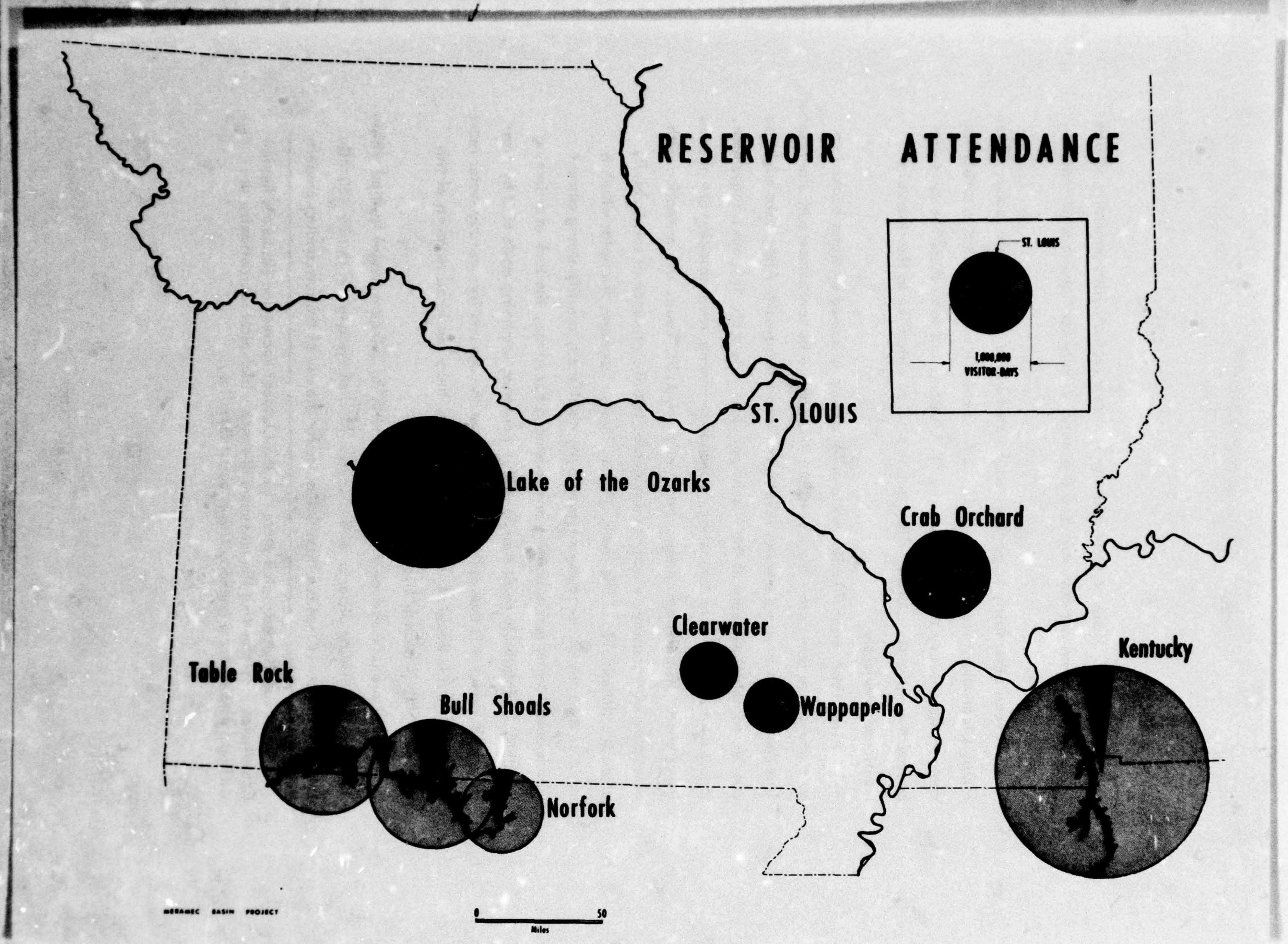
The northeastern fringe of the Ozarks, of which the Meramec Basin is a major part, forms the natural recreation area for St. Louis and environs. Both past and present use of this area has been more intense than that of other areas at similar distances from St. Louis (i.e., northern Missouri and Illinois). However, recreation activities tend to cluster around water, which at the present time is limited in extent within the Meramec Basin. Suitable large impoundments are not available in the St. Louis area for one-day or easy weekend trips, although many impoundments are located at slightly greater distances and are usable during three-day weekends and vacations. The importance of location near large population centers in influencing the usefulness for recreation of man-made lakes, has been discussed in the previous section. The following pages contain an appraisal of the degree to which existing lakes in the St. Louis area can be used to satisfy this demand.

Existing impoundments

Because of the existence of numerous reservoirs of varying sizes and with varying degrees of accessibility to the residents of St. Louis, any discussion of the need for reservoir recreation in the Meramec Basin must include some consideration of the extent to which this demand for reservoir recreation is being satisfied, or can be satisfied, by impoundments already existing or definitely scheduled for construction.

Several large reservoirs are located within 250 air miles of St. Louis (as shown in Figure 2). Many smaller reservoirs, not shown on this figure, are also located within this area.

The largest and most attractive of the large reservoirs (Kentucky Lake, Lake of the Ozarks, and the White River reservoirs) are located at distances too great to be convenient for one-day trips. All are located in the 150-250 mile distance zone


RESERVOIR ATTENDANCE
ST. LOUIS
1,000,000
VISITOR-DAYS
ST. LOUIS
Lake of the Ozarks
Crab Orchard
Clearwater
Wappapello
Kentucky
Table Rock
Bull Shoals
Norfork
MERAMEC BASIN PROJECT
0
50
Miles

from St. Louis.[10] Visits to these lakes by St. Louis recreationists generally require periods longer than one day, and are, therefore, usually confined to week-end or vacation visits.

Several other fairly large lakes are located in the 100-150 mile zone. These lakes, Clearwater, Wappapello, and Crab Orchard are better located to satisfy the demands for one-day recreation trips by St. Louisans, but even these are somewhat beyond the optimum distance. They are also not as attractive as the reservoirs mentioned previously.

Alton Lake, some 20 miles north of St. Louis, is formed by water backed up by a navigation dam across the Mississippi River above its confluence with the Missouri. This dam does not raise the water level greatly and as a result, Alton Lake might be considered an enlargement of the Mississippi River. As such, it is not a large lake. It is used primarily for motorboating, although swimming and picnicking are of some importance. Its chief advantages are its nearness to St. Louis, its connection with other parts of waterways which are navigable, and the presence of scenic bluffs along the Illinois side of the river. Among its disadvantages are water which is muddier than any of the reservoirs previously mentioned, a fairly strong current which occasionally makes boating and swimming hazardous, the lack of swimming beaches, its relatively small size, and the increasing use being made of it by commercial barges. It is thus able to satisfy part of the demand for one-day water recreation trips, but because of these characteristics, there are large segments of this demand which it is unable to satisfy.

There are a number of small lakes (in the 50 to 200 acre range) located within easy one-day driving distance of St. Louis. Most of these are in the 25 -50 mile zone. With few exceptions these lakes are for the use of the surrounding property

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[10] The recently completed survey by the Outdoor Recreation Resources Review Commission indicates that the maximum distance which most recreationists are willing to travel for a one-day trip is about 50 miles.

owners; recreational use by the public at large is therefore extremely limited. The smaller of these lakes are usable only for swimming, boating, and fishing. At a few of the larger lakes motorboating and water skiing are also included. Because of the limitations of the number of types of activities which are possible at these lakes, and because of the limited number of people who can be accommodated by these lakes, they have not provided the answer to the demand for water recreation facilities within an easy one-day drive of St. Louis.

Proposed impoundments

Several new reservoirs are being planned in the area north and east of St. Louis. Johanna Reservoir on the Salt River in northern Missouri is still in the talking stage. Shelbyville Reservoir, to the northeast of St. Louis on the Kaskaskia River in Illinois, is in the design stage. Both of these reservoirs are about as far away from St. Louis as the Clearwater-Wappapello-Crab Orchard group and are not likely to be superior in quality to these other reservoirs. Carlyle Reservoir on the Kaskaskia River about 40 miles east of St. Louis is already under construction and will have certain advantages in satisfying the St. Louis recreation demands. Its 40-mile distance from St.Louis puts it within an easy one-day drive of St. Louis. Its size will be large enough to accommodate considerable demand. Its large areas of open water should be ideal for speedboating and water skiing, and its shallow upper reaches should provide excellent habitat for water fowl. Although the quality of its fishing will be difficult to predict, there is no reason to believe that it will not be good. However, this reservoir too will suffer certain disadvantages. Its water is not likely to be as clear as that found in reservoirs in the Ozarks, nor is its flat, treeless shoreline likely to be as attractive. Relatively large horizontal fluctuations of the shoreline are likely to make difficult such shoreline uses as swimming, picnicking, and cottage site development. Because of these factors, Carlyle Reservoir is not expected to fully satisfy the demand for recreation in St. Louis.

Even after the construction of presently proposed reservoirs, the need will still exist for large water surfaces, in attractive settings, with good public access and control, within one-day driving distance of St.Louis. The Meramec Basin is ideally suited to satisfy these needs.

Meramec Reservoir Attendance Estimations

The problem of estimating recreation benefits at proposed reservoirs is a major one. Most methods of benefit measurement are based in some way on the use which the recreation facilities receive. An estimate of the use which a proposed reservoir will receive is therefore a necessary first step in estimating recreation benefits. This section is devoted to the problems of predicting reservoir use; the succeeding section is devoted to methods of measuring recreation benefits and how they apply to specific Meramec proposals.

What is the demand for water recreation at a potential multiple purpose reservoir? St. Louis, with a metropolitan population of more than 2,000,000 generates considerable demand. The nearest large impoundments are shown in Figure 2, with circles proportionate to total visitor-day attendance and pie sectors proportionate to estimated St. Louis visitor-days, ranging from 4% at Kentucky Lake on the southeast to 50% at Clearwater in the center.[11] Generally speaking, the nearer the lake, the greater the St. Louis attendance, as would be expected. Some variation occurs because of size and quality of the lakes, as will be noted later.

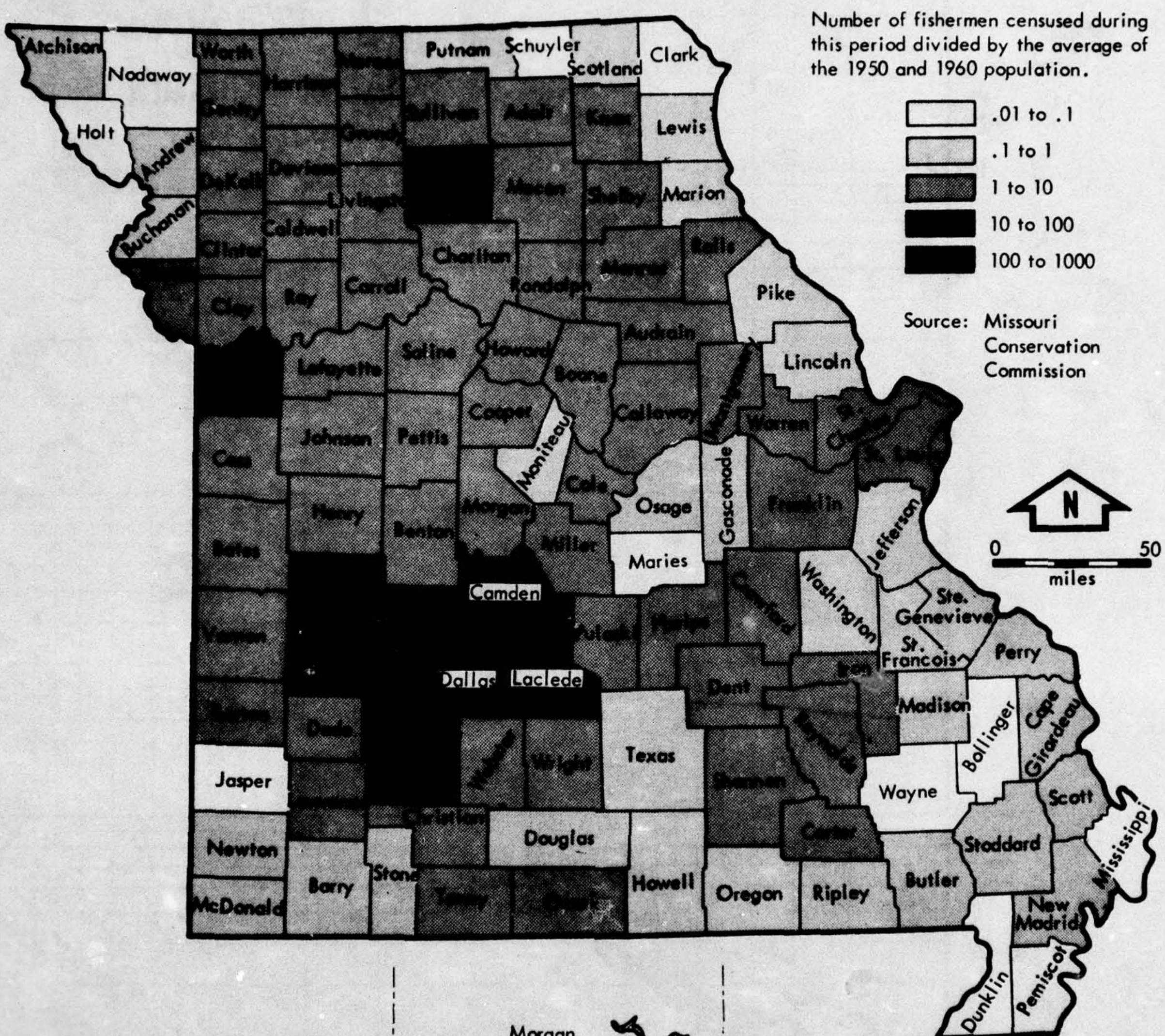
In order to determine the drawing power by distance zones of the various lakes, information on origin of visitors by small geographic divisions was sought. The biggest block of data came from unpublished creel census reports of the Missouri Conservation Commission which show origin of visitors by counties (for further details see the separate Creel Census Appendix). These were based on several thousand sample interviews over a period of years on various arms of lakes, or for whole impoundments in the case of the smaller lakes (Clearwater, Taneycomo, and Wappapello). These data were then converted into county per capita indices and mapped. Figure 3 is one representative map. Note generally how attendance decreases with distance. These indices were then plotted on logarithmic paper (Figure 4), and regression or trend lines fitted by inspection. The fit was fairly

[11] Alton Lake nearby on the Mississippi is not considered because it has different characteristics from the others in the universe, although it does figure in St. Louis recreation and has some attractive features.

Lake of the Ozarks, Niangua Arm

INTENSITY OF USE BY FISHERMEN

1950 - 1954, 1956



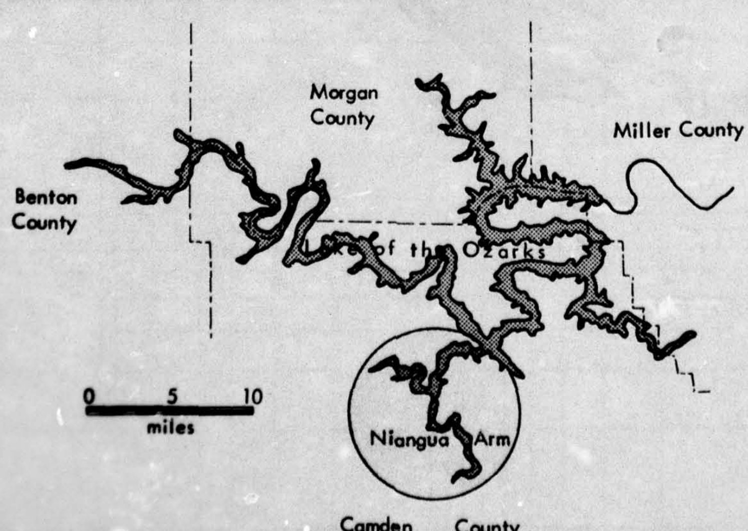
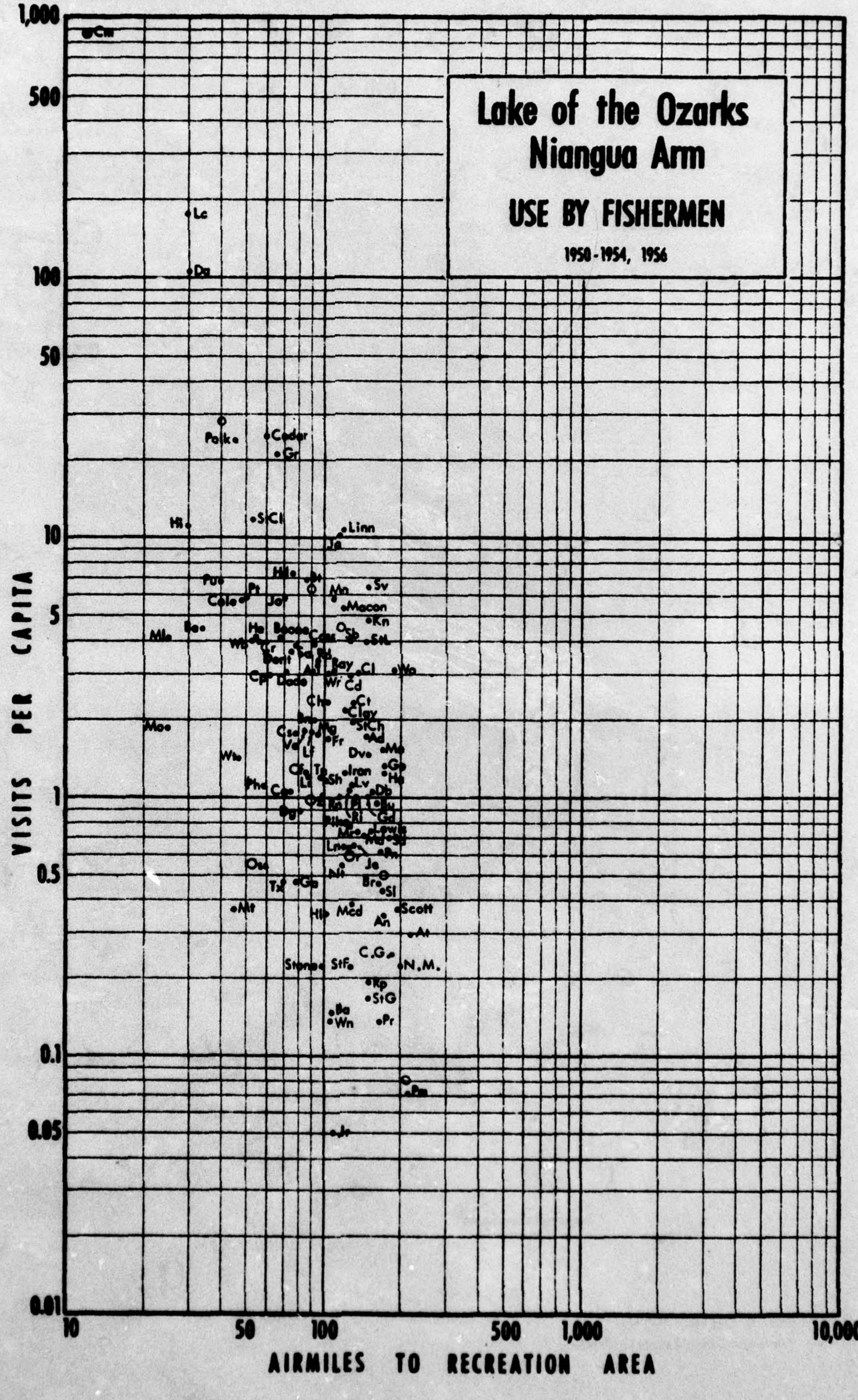


Figure 4
SAMPLE VISITOR-DISTANCE GRAPH



close, but there was also considerable scatter, in large part occasioned by differing social and economic characteristics of the sample units and by smallness of sample when applied to small counties. The slope of the lines fell off, however, in an essentially linear fashion and varied from a drop-off ranging from about the square of the distance to the fourth power.

The fact that the decline was so relatively rapid with distance might be construed as an indicator of the similarity and substitutability of one impoundment for another. Similar calculations which we and others have made for more nearly unique attractions such as Grand Canyon show a more gradual decline at a rate less than distance squared.[12] However, these more gradual declines represent the effect of combined visits to several western attractions pulling simultaneously, whereas impoundments of the type envisioned for the Meramec are more likely to generate single-purpose trips of shorter duration.

In addition to the creel census data other sources of data have been utilized including an intensive survey of five Missouri state parks conducted jointly by the Meramec Basin Project and the Missouri State Park Commission in 1960.[13] Based on data from these various sources, the median drop-off by the cube of the distance was taken and plotted on the logarithmic graph, Figure 5. The horizontal axis shows distance from reservoirs; the vertical axis shows per capita attendance.

On this graph two other regression lines are indicated: (1) a high representing generally high per capita attendance expectation from urban, high income counties, and/or to reservoir of high quality, and/or lack of intervening opportunities from closer impoundments suitable for recreation, (2) a low representing rural, low income counties and/or lower quality impoundments and/or presence of intervening opportunities for recreation at closer impoundments. The shaded zone represents generally the category in which St. Louis visitors fell.

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[12] Marion Clawson, Methods of Measuring the Demand for and Value of Outdoor Recreation. Resources for the Future Reprint No. 10. Washington, 1959. Our calculations were made from National Park and other surveys.

[13] For details see the separate appendix, "State Park Recreation Survey Results."

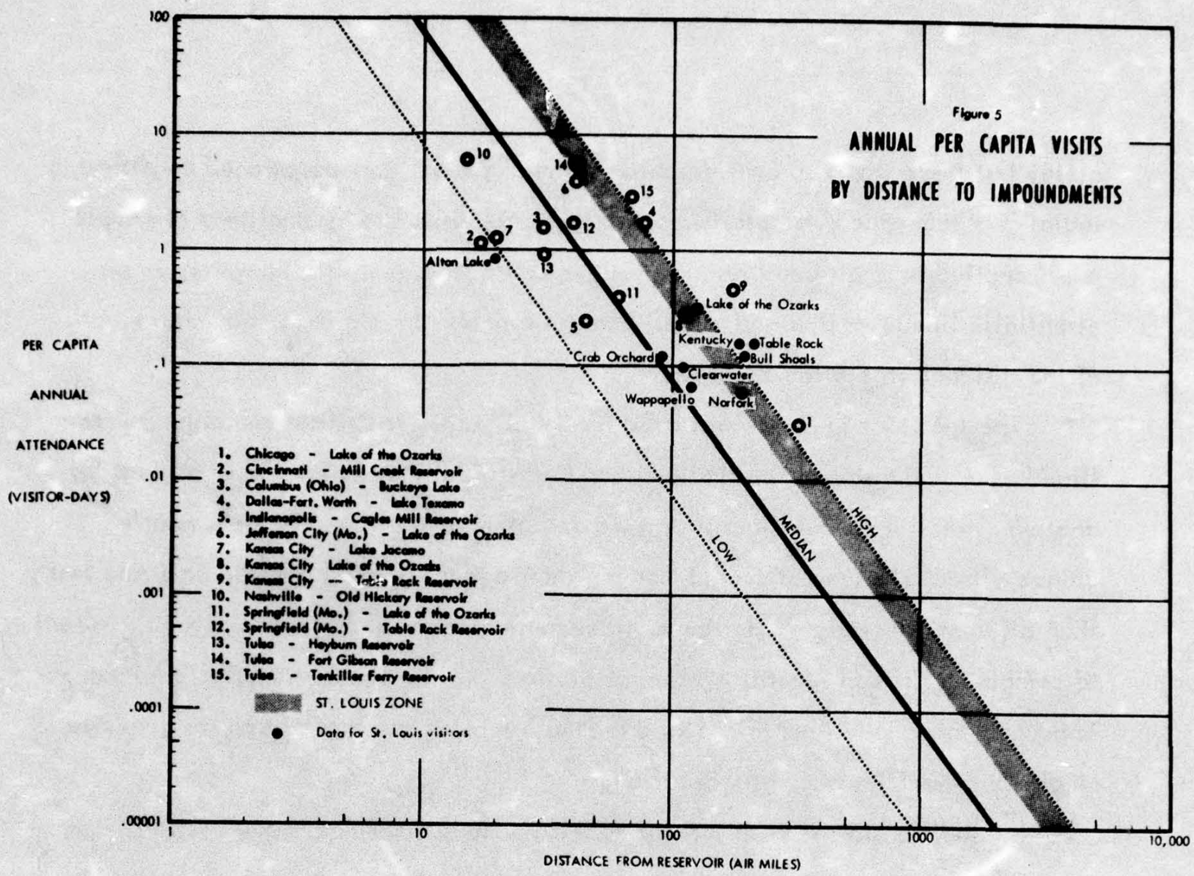

Figure 5

ANNUAL PER CAPITA VISITS BY DISTANCE TO IMPOUNDMENTS

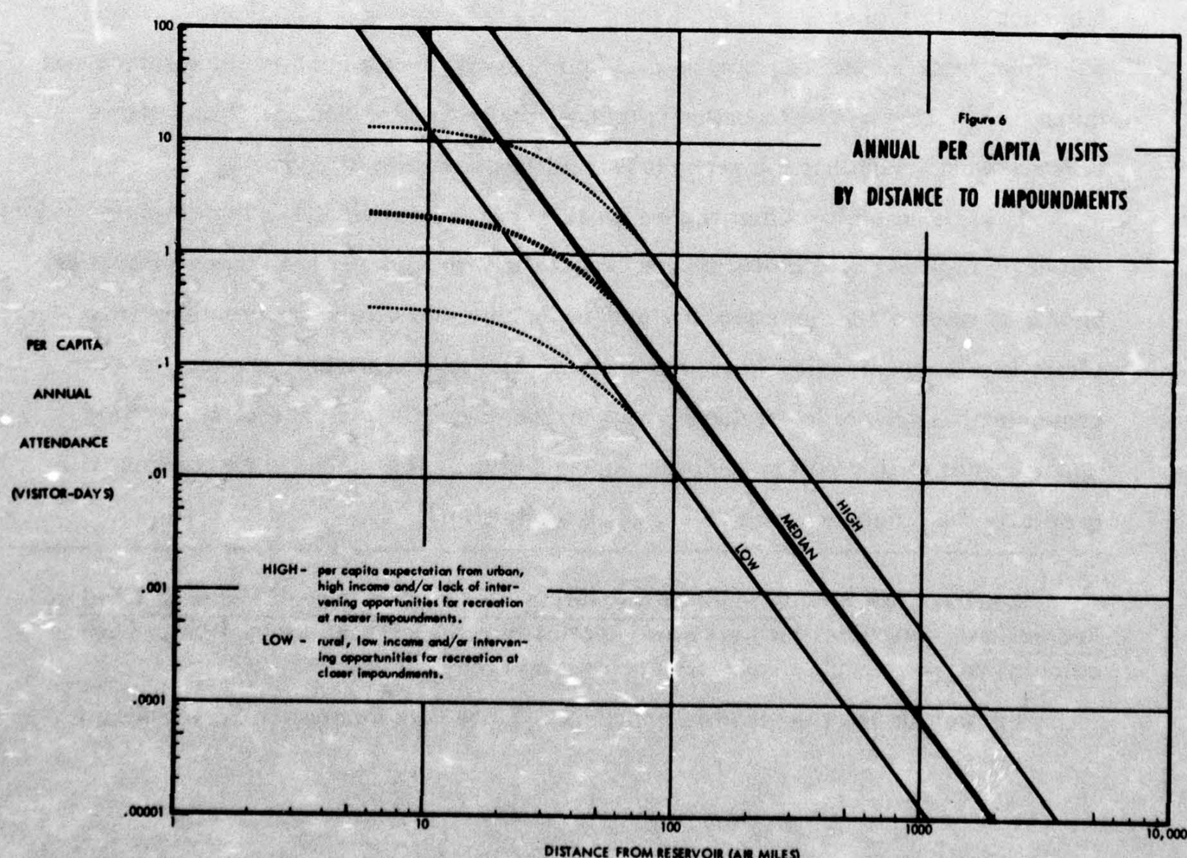

Figure 6

ANNUAL PER CAPITA VISITS BY DISTANCE TO IMPOUNDMENTS

To find a starting point for the lines on this graph, since the initial data simply give an index of rate of decline with distance, it was necessary to make further calculations. These yield a median estimate of 10 visits per capita at a distance of 20 miles. This was based on more than a dozen sample calculations for counties near reservoirs. An example will illustrate the method. Wayne County, a rural county in the Ozarks, whose mid-point is about 20 miles from Clearwater Lake, a 1,600 acre, relatively small reservoir, had 11.8% of the creel census fishermen visitors sampled at the lake; multiplying this by the total attendance of 414,000 reported by the Corps of Engineers, gives a figure of 49,183, which, when divided by the population of the county, gives a figure of 5.2 visitor-days per capita per year from that county. Other calculations for other counties at similar distances and at other impoundments showed a range from 1.6 up to approximately 30, with 10 apparently a reasonable median. In many reservoirs it was possible only to compute a still higher upper limit because the creel samples applied only to one arm of the lake and total attendance figures were available only for the whole lake.

The procedure thus for making the estimate of ten was not entirely satisfactory, but seems to be verified by other calculations. As an illustration and additional check on the regression lines, the St. Louis per capita visitor-days at the eight major impoundments have been plotted on the graph. These St. Louis visitor-days have been estimated from a variety of sources, and are only approximations; yet they are somewhat independent and are isolated from the general calculations which went into the regression lines and anchor points. Note that five of the impoundments are in the high zone or just beyond, and three in the median zone. The five high ones are all larger, better impoundments; the three lower ones, Crab Orchard, Clearwater, and Wappapello are all smaller and generally poorer either in setting or development. This may explain the difference. Data for several other cities and lakes have been obtained and are also indicated in Figure 5.

Figure 5 then represents the unadjusted attendance prediction model. Further adjustment is necessary because the linear model shown in Figure 5 is not adequate to predict attendance from nearby distance zones. The availability of data is limited

for zones within 50 miles of a recreation area, and attendance predictions dealing with nearby areas are therefore less certain. However, based on the few situations for which information is available, an estimate has been made of the extent to which the attendance-distance line departs from linearity. Taking this departure into account, a new curve has been drawn (Figure 6) which shows the tapering off at nearer distances. From this graph attendance by zones can be estimated around any reservoir essentially similar in size and character to the average of the other reservoirs. For a reservoir 50 miles from St. Louis, for example, a figure of four visits per capita per year is read from the "high" line at the 50 mile distance. (Remember the graph scales are logarithmic.)

The actual calculation of predicted attendance is shown in Table 1 where the per capita annual visits anticipated from each zone's characteristics is multiplied by the zone's population to give predicted total annual visitor-days in the last column. Note the overwhelming contribution of metropolitan St. Louis with its 2,000,000 population, which alone accounts for more than 80% of the visitor-days.

Estimation of Benefits from Meramec Reservoirs

Once the problem of predicting reservoir attendance has been dealt with, a new and greater problem presents itself. This is the measurement of recreation benefits.

Recreation benefits are probably the most difficult to measure of all the benefits which might accrue from water resources development. Benefits from recreation are often considered to be intangible, and therefore difficult or impossible to measure. Unlike hydroelectric power or water for irrigation, recreation benefits in most cases do not have an institutional framework by which they may be sold directly to the public. It is likewise difficult to measure recreation benefits in terms of alternative costs which may be unnecessary by a water resource development -- a method often used to measure benefits from flood control, irrigation or low flow augmentation. However, in order to compare recreation with other uses of such a development -- uses which are possibly competing -- it is necessary that these benefits, wherever possible, be reduced to monetary terms, the only readily available common denominator

Table 1

ESTIMATED ATTENDANCE AT HYPOTHETICAL MAJOR IMPOUNDMENT
50 AIR LINE (60 ROAD) MILES FROM ST. LOUIS

Distance Zones from Hypothetical Reservoir	Population in Zone	Per Capita Annual Visits Category[a]	Per Capita Annual Visits Number	Total Annual Visitor-days
0-10	20,000	median	3	60,000
10-20	40,000	median	2	80,000
20-40	90,000	high	8	720,000
40-60	2,000,000[b]	high	3	6,000,000
60-100	300,000	median	.2	60,000
100-200	2,000,000	median	.03	60,000
200-300	10,000,000	median	.005	50,000
300-500	30,000,000	median	.001	30,000
Beyond 500	(Rest of U.S.)	Estimate		50,000
			Total	7,110,000

[a]Categories refer to per capita annual visits expected based on numerous origin surveys in 1960, at large impoundments in Missouri, Illinois, and Kentucky. High refers to per capita expectation from urban, high income and/or lack of intervening opportunities for recreation at nearer impoundments; low refers to rural, low income and/or intervening opportunities for recreation at closer impoundments. Median is average between two extremes.

[b]Includes most of St. Louis metropolitan area.

for all types of benefits. In an area such as the Meramec Basin, where recreation appears to loom large as a source of benefit in competition with the other multiple-purpose uses, it is all the more necessary that some monetary measure for recreation be found.

Some persons concerned with recreation argue that it is impossible to place a monetary value on recreation, and in some cases argue that it is even undesirable to try. One water resources expert expressed it this way; "Such purposes as recreation must therefore be judged on other [than monetary] criteria, for the use of the benefit cost analysis for them not only is invalid, but costs general doubt and suspicion upon procedures which can effectively serve a high purpose where they are appropriate."[14]

However, it must again be emphasized that the competition among various uses for limited resources is increasing and "there is considerable merit in the position that rational planning of resource development requires a value on recreation wherever it is one of the major uses of land or water."[15] Not placing a value on recreation is equivalent to placing zero value on it. Therefore any reasonable estimate of value is better than none at all. However, some still argue that a monetary value cannot be placed on essentially subjective experiences. These people overlook the fact that we do this all the time, not only for masterpieces of painting but also for education, health services, and many other aspects of life.[16]

However, this does not solve the problem -- what is the value of recreation in a particular place? Obviously, the ideal way to answer this question in the case of a reservoir would be to build a fence around the lake and charge admission of anyone who wished to use the lake. But such an arrangement, where access is completely controlled, would not in itself solve the problem of what people are willing to pay. Experimentation with fees would be necessary to find the right scale

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[14] Otto Eckstein, Water Resources Development. Harvard University Press, Cambridge, 1958, p. 41.

[15] Marion Clawson, Methods . . . . , p.3

[16] Ibid., p. 3.

of fees properly allocated among various types of uses such as fishing, water skiing, picnicking, boating, renting of lake sites, etc. Few existing lakes have been built with fences around them and data of this sort is consequently hard to obtain. Various schemes for evaluating recreation benefits have been tried by others and are now used by others -- none of which are entirely satisfactory. The more important of these are described below.

In the summary report of the previous Meramec investigation in 1949 the Meramec Field Investigation Committee[17] recommended the use of an arbitrary figure of $1.00 per visitor-day[18] -- a figure which is now used by a great many agencies in the recreation field. This $1.00 per visitor-day was assumed to be a reasonable rate which most people might be willing to pay, but there is no justification for its use beyond assumption. Other arbitrary fixed values per visitor-day are also used by some agencies. Some also differentiate on the basis of activity-days -- some types of recreation activities being valued more highly than others (e.g., camper-day, $2.00; sightseer-day, $0.50).

The cost method used by the National Park Service at one time adopted the policy of setting benefits equal to the cost of providing recreation facilities at a lake. This method merely begs the question: it does not provide an answer to the question of what is the recreation worth.

The gross expenditures method measures the total amount of money spent by recreationists. It assumes that recreation is worth to the recreationist at least as much as he is willing to pay. This method is used by some agencies in the state of California, but is more valuable as a measure of the impact of recreation on the economy of the local area rather than the satisfaction of the recreationist or the value of the recreation experience as such.

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[17] Meramec Cooperative Investigation Field Committee, A Program for the Meramec River Basin; Summary Report. 1949, p. 11.

[18] The visitor-day is a unit representing a full day or part of a day spent at a recreation area by a single visitor. This is not a satisfactory measure of attendance, but it is the one in use by practically all the agencies concerned with recreation, and will probably continue to be used since no one has devised anything better.

Another method attempts to evaluate recreation according to its contribution to the gross national product (a commonly accepted measure of economic welfare). There are several possible ways of going about this -- all of which eventually involve finding out what proportion of our national product is due to the additional productivity gained by individuals through recreation that would not have been gained otherwise. Obviously this method poses a great many difficulties both at the theoretical and operational levels.

The market value method attempts to use fees charged at private recreational developments as indicators of benefits. Difficulty arises in finding comparable recreational opportunities at which to measure these fees. A variation of this method seeks to establish benefits through calculation of land value changes.

By means of estimates of the value added by local business (which has some similarities to the market value method and the gross expenditures method) an attempt is made to separate out that portion of the gross expenditure which represents local economic activity or the value of the location as such.

The consumer surplus method essentially involved estimation of a demand curve for recreation (either by asking people what they would be willing to pay, or by calculating the effects of increased costs on demand). From this curve the amount of money that people would have been willing to pay rather than do without the recreation experience is compared with the amount they actually had to pay and the difference is considered a benefit.

The monopoly revenue method proceeds along similar lines. This method also uses demand curves to estimate the level of entrance fees and the nature of development that would yield maximum net revenue to the owner of a recreation area. It is similar to the fence-building method described previously.

Another method involves the calculations of cost savings (usually measured in travel costs) which accrue to a recreationist because he is able to use one recreation site as opposed to a more distant one.

Several of these methods will be examined in greater detail as they apply specifically to the Meramec proposals. These are the arbitrary value method, the land value method, and variations of the cost savings and consumers surplus methods.

Arbitrary value method

If the predicted attendance figures at the hypothetical impoundments in the Meramec are used, and the customary \$1.00 per visitor-day is used to evaluate the recreation benefits, very large recreation benefits would accrue -- on the order of \$4,000,000 to \$18,000,000 annually (depending on the distance of the reservoir from St. Louis). If the \$1.60 or \$2.00 figure is used, even larger recreation benefits would accrue. If it is assumed that these figures represent gross benefits, the accompanying costs must be subtracted to provide a figure for net benefits. Even the recreation costs (such as maintenance and repair) are difficult to estimate. Figures ranging from 10 to 35 cents per visitor-day are often used and seem reasonable. Using as an illustration 25 cents per visitor-day as the costs and \$1.00 per visitor-day as gross benefits, the net benefits would be on the order of \$3,000,000 to \$13,500,000. If the gross benefits per visitor-day were reduced to approximately one-third of the standard value (to 35 cents), net recreation benefits would be on the order of \$400,000 to \$1,800,000 annually. Even at this lower value they would still equal or exceed benefits from any other source.

Land value method

One of the best methods from the theoretical point of view, that of charging admission and service fees of anyone making use of a reservoir for recreation, has serious drawbacks in practice as mentioned previously. Few lakes have controlled access which will allow the charging of admission fees. There has been, however, some experience with lakes at which access is primarily through private property -- with the result that land values or net income from the land can be used to give some indication of the value of recreation at that particular lake. The results of some investigations along these lines are presented in more detail in Volume I, Chapter 4. It should be pointed out there that there is a problem of comparability between the lakes investigated and possible impoundments in the Meramec Basin -- primarily differences in size and location in relation to the market. The problem is to estimate the differences in land value between lake-shore land and land not located near a

lake. Differences of several hundred to several thousand dollars per acre were indicated. On this basis recreation benefits at a Meramec reservoir would be on the order of several million dollars annually. Specific benefits would depend on the size of the lake, its nearness to St. Louis, and the number of users of the lake.

Travel savings benefits

Tables 2 and 3 present another method for calculating travel benefits -- a conservative one -- based on the diversion of existing visitors from more distant impoundments to a closer one. The principle implied is that cutting down travel by locating activities closer is just as legitimate a benefit as building a highway to cut down travel costs.

Table 2 details the distance from St. Louis of the eight nearest large reservoirs and their attendance. These are the same reservoirs shown on the map and graph, (Figures 2 and 5).

Table 3 indicates the visitor miles saved by locating impoundments closer to St. Louis. The critical figure here is the estimate of one-third diversion from more distant impoundments. This is based on some questions asked at four Missouri State Parks in our joint sample survey in 1960 and particularly the question: "If a lake similar to this one were built half as far away from your home, would this decrease your visits to this lake?" to the extent of "eliminate completely, reduce greatly, reduce slightly, no effect, don't know." These were scored 100%, 75%, 25%, 0 and the last, "don't know" (responded by about 20%) allocated accordingly. The combined score was one-third diversion. The lakes proposed are only 25-60 air miles from St. Louis -- much less than half the distance to most of the other impoundments; one-third diversion, therefore, is undoubtedly too low, and one-half or some other figure might be better. However, asking people what they might do before they do it is uncertain, so the conservative diversion of one-third was used. The other item, average trip length of four days, came from the same survey.

The results of this procedure are summed up in the last column "Total Visitor Miles Saved." These figures are increased 10%, paragraph B, to take account of other visitors in still closer zones who would also save miles.

Table 2

ATTENDANCE DATA FOR EXISTING IMPOUNDMENTS NEAR ST. LOUIS (1960)

Impoundment	Distance from St. Louis Air Line	Distance from St. Louis Road	Total Visitor-days(1960)[a]	St. Louis Visitor-days[b] % of total	St. Louis Visitor-days[b] Number
Lake of the Ozarks	135	180	4,000,000 est.	15	600,000
Clearwater Reservoir	105	130	410,000	50	210,000
Wappapello Reservoir	115	140	460,000	30	140,000
Bull Shoals Reservoir	200	270	2,580,000	10	260,000
Norfork Reservoir	190	270	1,120,000	10	110,000
Table Rock, Taneycomo	220	270	3,000,000 est.	10	300,000
Kentucky Lake	180	230	7,500,000	4	300,000
Crab Orchard Lake	90	120	1,200,000	20	240,000
Total			20,290,000		2,160,000

[a]Lake of the Ozarks -- local estimates; Crab Orchard -- U.S.Fish and Wildlife Service; Kentucky Lake -- TVA. All others -- U.S.Corps of Engineers.

[b]Based on Missouri State Conservation Commission creel census data, varying years; Meramec Basin Project-Missouri State Park sample surveys, 1960; U.S.Fish and Wildlife Service, 1960 (Crab Orchard); Meramec Basin Project and Kentucky State Parks, 1960 (Kentucky Lake).

Table 3

ANNUAL TRAVEL SAVINGS

Impoundment	Distance from St. Louis (road miles)	Annual Round Trips[a] by St. Louis Visitors	Visitor Miles Saved by Construction of Reservoir at: Meramec Park (70 road miles)	St. Clair or Virginia Mines (55 road miles)	Cedar Hill (45 road miles)	Pacific or Byrnes Mill (30 road miles)
A. Lake of the Ozarks	180	50,000	11,000,000	12,500,000	13,500,000	15,000,000
Clearwater	130	18,000	2,200,000	2,700,000	3,100,000	3,600,000
Wappapello	140	12,000	1,700,000	2,000,000	2,300,000	2,600,000
Bull Shoals	270	22,000	8,800,000	9,500,000	9,900,000	10,600,000
Norfork	270	9,000	3,600,000	3,900,000	4,100,000	4,300,000
Table Rock, Taneycomo	270	25,000	10,000,000	10,800,000	11,300,000	12,000,000
Kentucky Lake	230	25,000	8,000,000	8,800,000	9,300,000	10,000,000
Crab Orchard Lake	120	20,000	2,000,000	2,600,000	3,000,000	3,600,000
Total Visitor Miles Saved			47,300,000	52,800,000	56,500,000	61,700,000
B. Plus 10% to account for non-St. Louis visitors			52,000,000	58,100,000	62,200,000	67,900,000
C. Annual Operating Savings (1.39 cents per visitor mile)[b]			723,000	808,000	865,000	944,000
D. Annual Time Savings (1.43 cents per visitor mile)[c]			744,000	831,000	890,000	970,000
E. Total C & D			1,467,000	1,639,000	1,755,000	1,914,000
F. Divided by 2 to allow for overestimation in official attendance figures			734,000	820,000	878,000	957,000

[a] Based on average trip length of four days, and diversion of one-third visitors as determined from Meramec Basin Project-Missouri State Parks joint survey, 1960.

[b] Variable cost of 4.85 cents per vehicle mile (9.76 cents minus 2.54 depreciation, 1.08 garage, and 1.29 insurance) divided by 3.5 passengers per vehicle equals 1.39 cents per visitor-mile. [Number of passengers from State Park survey; vehicle costs from Wilbur Smith and Associates, Future Highways and Urban Growth, New Haven, 1960, pp. 281, 285.]

[c] Time saved at $2.00 vehicle hour or $.58 per visitor hour ($1.50 per hour for driver plus $.50 for one passenger, 0 for other 1.5 passengers at average speed 40 mph); 1.43 cents per visitor-mile.

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In paragraphs C, D, and E of Table 3 the visitor miles saved are converted into dollars, again on a conservative basis.

No account is taken of possible loss of business diverted from competing impoundments. These impoundments were built primarily on the basis of other benefits (power, flood protection, etc.) and thus represent such costs, and only the recreation facilities per se need to be considered. The overriding practical consideration, however, is that recreation is growing so rapidly that there would be only a very short term loss, if any, from the small diversions, so that the net disbenefit would be minute.

One reduction, however, might be made to take account of inflation in the official attendance figures (counting some ten minute stops as visitor-days, etc.). If they are inflated by a factor of two, about the maximum reasonable to expect, then the various savings would drop one-half. These are indicated in the last line of paragraph F of Table 3. These savings are only a partial measure of benefits since they do not measure newly generated business (75%-90% of the total expected). Even so, this clear savings represents annual benefits of $700,000 to $1,000,000 — a substantial sum.

Potential net benefits (consumer's surplus)

From the attendance prediction model (Figure 5) and the estimated attendance at a hypothetical reservoir 50 air miles from St. Louis (Table 1), a still closer estimate of the total net benefits at this reservoir can be made which includes both diverted and generated visitor days. This can be done by actually estimating the number of people willing to go farther than 50 miles on the basis of our measures elsewhere. For the case in question 8,000,000 visitor days (unadjusted) are willing to go from St. Louis to this reservoir, but of these 8,000,000 visitor days, 4,600,000 would be willing to go at least 60 miles, 2,880,000 would be willing to go at least 70 miles, etc. For those willing to go at least 10 miles farther, they in essence are given a gift of at least 20 miles round trip; those willing to go 20 miles farther are given 40 miles, etc.

These gifts of extra miles can be converted into dollars on the basis of three cents per visitor mile, which is composed of about half vehicle operating costs, half modest estimates of time savings (footnotes b and c, Table 3). These have been summed in Column 5 of Table 4 "Travel Savings for Impoundment 50 miles from St. Louis". This table is self explanatory. Column 2 indicates number of visitor-days (estimated from Figure 5 the prediction graph) for distances shown in Column 1; Column 3 shows the number of visitor-days in each incremental ten mile block of distance; Column 4 represents the amount saved per visitor-day mile and Column 5 the total time and travel savings for each ten mile block.[19] The total savings in Column 5 are summed to give a total of about $4,728,000. This represents the total net benefits. These benefits would be greater for impoundments closer to St. Louis because of larger attendance and distance savings. We have then divided this sum by 8,000,000, the theoretical unadjusted attendance, to give the figure of 59 cents per visitor day which we have rounded off to 60 cents. This is the figure used in all the benefit-cost calculations in this report.

All visitors do not obtain this theoretical savings -- some get less, some get more -- but splitting this savings equally seems reasonable, although further refinement and research might well make another allocation. Trice and Wood, using a somewhat similar method, essentially based on the difference between the median distance traveled and almost the greatest distance traveled (the 90th percentile), arrive at a figure of $2.00 in California.[20] Our estimate is more conservative.

Still another way of treating the problem is to figure what attendance and revenue would be received if admission were charged for each visitor -- if a fence were built around the reservoir and an entrance fee charged for every visitor day. On this basis, at 39 cents, 2,880,000 visitors theoretically would be willing to spend this amount giving a total revenue of $1,132,000; at 69 cents, 1,920,000 visitors, total revenue $1,324,000; at 99 cents, total revenue $1,326,000; at $1.29, total revenue $854,000 and so on in decreasing amounts. Thus the price on an admission charge basis producing the greatest revenue appears to be about $1.00.

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[19] The first group is averaged at 3 miles, the next at 13, etc.

[20] Andrew H. Trice and Samuel E. Wood, "Measurement of Recreation Benefits" Land Economics. Aug. 1958, pp. 195-207.

Table 4

POTENTIAL TRAVEL SAVINGS FOR IMPOUNDMENT 50 MILES FROM ST. LOUIS

Distance from St. Louis (air miles) 1	Visitor (Days) Willing to go Distance in Col. 1, or farther[a] 2	Approx. Visitor (Days) in each incremental ten mile block 3	Travel & Time Costs Savings Cents Per Visitor-Day[b] 4	Travel & Time Costs Savings Approx. Total (Col.3xCol.4) 5
50	8,000,000			
		3,400,000	9	$304,000
60	4,600,000			
		1,700,000	39	669,000
70	2,880,000			
		960,000	69	658,000
80	1,920,000			
		580,000	99	575,000
90	1,340,000			
		360,000	129	470,000
100	980,000			
		246,000	159	390,000
110	734,000			
		170,000	189	321,000
120	564,000			
		121,000	219	265,000
130	443,000			
		89,000	249	222,000
140	354,000			
		67,000	279	187,000
150	287,000			
		51,000	309	158,000
160	236,000			
		39,000	339	132,000
170	197,000			
		32,000	369	118,000
180	165,000			
		25,000	399	100,000
190	140,000			
		20,000	429	86,000
200	120,000			
		16,000	459	73,000
210	104,000			
		Total		$4,728,000
				($.59 per visitor-day)

[a] Unadjusted; for adjusted figures to proposed impoundments see Table 1.

[b] At $.03 per visitor-day mile (Footnotes b and c, Table 3) x one-half round trip distance (represents round trips divided by two days, the average duration of trip as determined by survey at Meramec State Park).

This essentially is the optimum point on a theoretical demand curve. This figure yields more net benefit than the diversion estimate in the preceding section. It, however, is not the optimum price at all reservoirs; at reservoirs closer to St. Louis where most of the proposed alternatives are, a higher total net benefit would accrue. Either a higher price could be charged or at a low price a much larger attendance would be expected.

The various user fees suggested in Volume 1, Chapter 4, would have somewhat the same effect as an entrance fee and to this extent would cut down attendance somewhat. However, at the competing lakes used in our calculations, fees are also charged of many or most recreationists making use of the lake. The fees to be charged at a Meramec Lake when spread over predicted attendance would be very small and would have only a minor effect. Hence they have not been taken into consideration.

For all the reasons noted above plus the convention of using a single visitor-day benefit partly because costs are so figured, the rough figure of 60 cents per visitor-day has been adopted. Further analysis could refine the figure, probably justifying a somewhat higher amount at nearer reservoirs, but, as noted, the benefit figure will vary with the ability and desire of the individual visitor to pay.

Using figures of 60 cents per visitor-day for gross recreation benefits and 20 cents per visitor-day for annual recreation costs yields initial net benefits of \$1,600,000 to \$4,800,000, depending on which reservoir is constructed. These benefits, coupled with the lack of sizable benefits from other sources, make it difficult to ignore the fact that recreation is the major potential use of any reservoir constructed in the Meramec Basin.

Impact of Recreation on the Local Economy and on St. Louis

An important by-product of reservoir construction in the Meramec Basin would be its effect upon the economy of the basin and the St. Louis area. Much of the basin area has been losing population, or at best remaining at the same level. The

St. Louis area, although growing, has not been keeping up with cities of comparable size in providing new industrial employment opportunities. Many persons feel that reservoir construction in the Meramec Basin would help to reverse these trends. The possible economic effects on these areas is examined on the following pages.

The degree to which a recreation development provides stimulation to a local economy is often overestimated. However, there is no doubt that in many other parts of the Ozarks, reservoir recreation provides the only bright spot in an otherwise lagging economy. In some cases it is the original inhabitants of the area who are the main beneficiaries of a recreation industry, but in others it is people who have moved in from outside.[21] There is little doubt that many jobs (mostly seasonal) would be created if reservoir recreation were developed in the Meramec on a scale comparable to that at Lake of the Ozarks or in the White River area.

Development of a recreation industry should increase expenditures and net revenues in a region. Money would be brought into the area in the form of wages and profits for basin residents. A rise in the value of land and facilities should result in an increase in tax revenues, although more services will have to be provided by local governments. Per capita expenditures by recreationists have been variously estimated to range from \$1.00 or \$2.00 per day[22] to \$25.00 per day.[23] Surveys at several National Parks provide a figure of about \$5.00 per capita per day.[24]

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[21] According to a recent survey, about 60% of the operators of tourist-oriented businesses in the Ozarks were actually born in the Ozarks. Ronald Bird and Frank Miller, Contributions of Tourist Trade to Incomes of People in Missouri Ozarks, University of Missouri Agricultural Experiment Station Research Bulletin 799, Columbia, 1962, p. 3.

[22] C. S. Van Doren, Recreational Usage and Visitors Expenditure, Gavins Point Dam and Reservoir, Summer, 1959, State University of South Dakota Business Research Bureau Bulletin Number 65, 1960, p. 29.

[23] Harry G. Clement, River Bend: Its Potential Economic Significance for Maryland, Maryland Department of Economic Development, Annapolis, 1961, p.11.

[24] Glacier National Park Tourist Survey (1951), \$4.12; Shenandoah National Park Tourist Study (1952), \$6.79; Great Smoky Mountains National Park Travel Study (1956), \$4.66; Studies conducted by the respective State Highway Commissions and the U. S. Bureau of Public Roads.

Because there would probably be more one-day visitors and less overnight visitors, this expenditure might be somewhat less in the Meramec. On the other hand, if a lake were built close enough to St. Louis to permit persons who worked in the city to commute from permanent residences on the lakes, the infusion of capital into the local economy might be considerably greater. About 3/4 of the money spent by tourists goes into food, lodging, and transportation.

Studies made by Arthur L. Moore for the Outdoor Recreation Resources Review Commission[25] reveal interesting contrasts in economic health between certain Ozark counties in Missouri, Arkansas, and Oklahoma located along the shores of major reservoirs, and counties not so located. During the past ten years both groups lost population, but the loss in reservoir counties was only 8% as compared to 25% for the non-reservoir counties. Reservoir counties led non-reservoir counties in certain measures of economic growth: increase in per capita income, 57% to 23%; increase in local tax collections, 64% to 4%; increase in retail sales, about 70% to about 30%. Probably the major impact on the local area would be the general improvement of living conditions. Desirable living conditions are often an important factor in attracting and holding industries and other businesses.[26] Improvement in the competitive position of the Meramec area by improving living conditions might be the most important effect of reservoir development.

St. Louis would be similarly affected. Some additional spending for water recreation equipment would probably take place in St. Louis, although a large portion of this spending would merely represent a transfer of spending from another sector of the economy. The desirability of the St. Louis area as a place to live would be influenced by the availability of nearby water recreation facilities. Larger firms are finding this an increasingly important factor in attracting top-flight personnel. The importance of this effect should not be underestimated.

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[25] ORRRC, p. 76

[26] Edward L. Ullman, "Amenities as a Factor in Regional Growth", Geographical Review, Vol. XLIV, No. 1, 1954, pp. 119-132.

Characteristics of Needed Recreation Facilities

The reservoir characteristic which probably has most effect on use is distance from potential users. The lower parts of the Meramec Basin are ideally situated from this standpoint. Other important factors are (1) general appearance of the shoreline, (2) size, shape, and stability of the water surface, (3) water quality, (4) depth of water and seriousness of obstruction hazards, (5) the climate of the area, and (6) quality of the fishing. All are discussed at greater length in Appendix B.

With regard to general appearance of the shoreline, the Meramec is comparable to other parts of the Ozarks; and is considerably better than most parts of the Midwest outside of the Ozarks. Rolling to steep hills, fairly heavily wooded and generally devoid of man-made eye-sores, are characteristic of the area.

The size of a reservoir near St. Louis should be large enough to handle the multitude of recreationists who will make use of it. (An alternative, probably more expensive, would be to build a very large number of smaller lakes.)[27] For recreational use it is important to have a stable water surface. If water levels fluctuate greatly, use of the reservoir for recreation will be impaired. (Separate Appendix to this chapter.) The practical limits on the amount and timing of reservoir fluctuation are not fully known, but it is imperative that fluctuation be kept to a minimum.

Water quality is important, although even very muddy reservoirs will be heavily used if other characteristics are desirable. Water quality in the Meramec is best in the south-central headwaters; the least desirable areas are in the Dry Fork of the Meramec or Bourbeuse rivers.

Climate also affects the use of a reservoir. Lakes in Florida receive year around use; the use of those in Minnesota is limited to two or three months. The fairly moderate climate of the Meramec Basin permits most types of water-based activity during four or five months of the year, and other recreation activity during several more months. The hot midsummer weather makes water particularly desirable for recreation.

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[27] Some possibilities for construction of small lakes are listed in Appendices III and VIII to the 1949 report of the Meramec Cooperative Investigation Field Committee, and in Harland Bartholomew and Associates, Land Development Study: Washington County, Missouri, St. Louis, 1960.

The facilities needed at a large lake near St. Louis would differ somewhat from those needed at most other lakes. (See Figure 7.) A Meramec lake, located relatively close to the majority of its users, would experience a demand configuration similar to that at the left side of the chart, in contrast to the configuration at right which is typical of most existing reservoirs. Picnicking and other day-use activities would be much more important. Camping would be relatively less important, although the absolute number of campers would be comparable to other lakes. (While picnicking and camping are of equal importance at distances of several hundred miles, at distances of less than 50 miles camping has only one-fifth to one-tenth the number of participants.) Differences in other activities are not as pronounced, although there is some tendency for participation in a number of activities to increase with distance from place of residence. The demand for week-end and vacation cottages (not shown on Figure 7) should be considerable -- particularly if the reservoir were located within easy commuting distance of St. Louis.

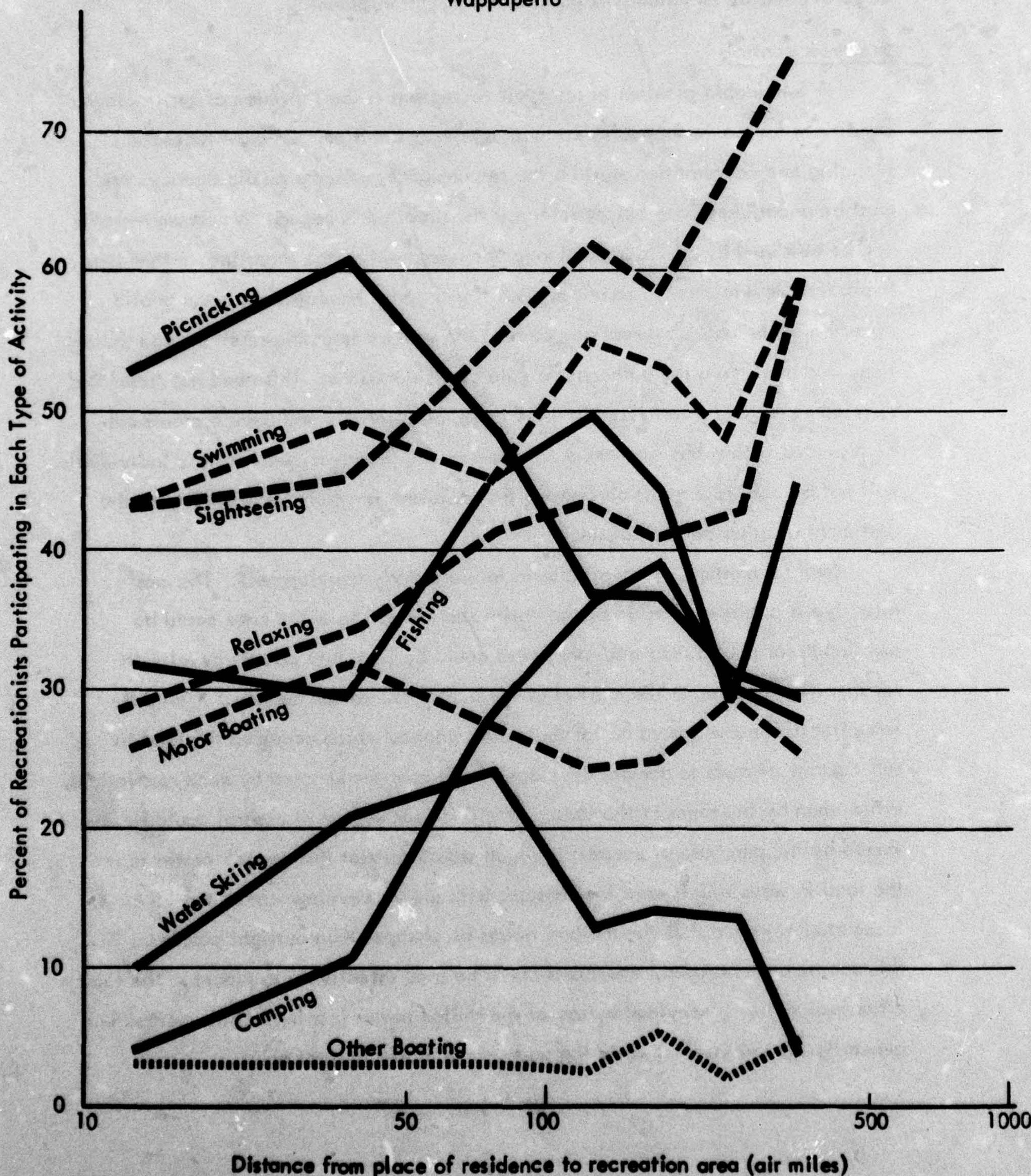
Summary of the Recreation Needs of the Meramec Basin and St. Louis

The recreation needs of the area have been detailed in previous parts of this chapter, and other aspects of these needs are further discussed in Volume I. (See pp. 49-50 for recommendations concerning recreation; pp. 55-79 for specific reservoir proposals; and pp. 81-86 for a discussion of problems of administration and financing of recreation developments.) It will be useful to end this detailed discussion of recreation with a summary of the recreation needs and problems of the Meramec Basin and the St. Louis area -- and a look at how these findings fit in with recommendations of the Outdoor Recreation Resources Review Commission resulting from their recently completed national survey.

The orderly development of recreation facilities is desirable to improve the attractiveness of the St. Louis region. The potential for such recreation development in the Meramec basin is great -- here exists a large scenic area close to St. Louis which has not been preempted by other uses, and which possesses a fairly mild climate conducive to outdoor recreation. The primary need is for mass water recreation facilities; however, enthusiasm for supplying the needed reservoirs should

RELATIONSHIP BETWEEN DISTANCE TRAVELED AND TYPES OF RECREATION ACTIVITY AT FOUR MISSOURI STATE PARKS (1960)

Lake of the Ozarks
Table Rock
Thousand Hills
Wappapello



not obscure the desirability of variety in recreation -- free-flowing streams should be available for people who prefer them, and other types of facilities should be made available. Balance is important in recreation planning.

Reservoir controls

A formidable problem in reservoir recreation is the provision of satisfactory conditions for maximum public use with minimum conflict. Overall recreation planning and coordination must be the responsibility of some public agency, and must be undertaken long before reservoir construction is begun. Maximum benefits can be obtained by an orderly, planned development of the shoreline, rather than haphazard development. To accomplish this orderly development, some public agency must be able to direct and control the uses made of the reservoir and shoreline, and must have the authority to enforce its decisions. This need not mean that development will be restricted; a wide range of activities and developments can be provided within this framework. It does mean, however, that private individuals will not be able to exploit portions of the shoreline for their own benefit, to the detriment of other potential users.

Several methods are available to insure orderly development. The most effective is public ownership of the entire shoreline. Selected sites could be developed for public use, and other sites could be leased to private developers for specified uses under the control of the public recreation agency. A slightly less effective means would be for the public agency which acquired the land to sell certain parcels to private developers with controls imposed by deed restrictions rather than by the terms of the lease. A still lesser degree of control could be obtained by the purchase of easements which would restrict the owner's power to use the land in ways which were inconsistent with proper development of the lake. It is sometimes argued that this method would be cheaper than outright purchase; if this can be demonstrated, easements could be used effectively in places. The least effective control is provided by use of the police power (zoning). This method has generally proved ineffective in the past, particularly in rural areas.

> The Corps of Engineers, when it comes to local assistance and to recognition of the fact that a large reservoir creates problems for which no local answer exists or is possible, must take on at least a limited degree of the TVA's familiar planning function.
>
> As it is, the Corps builds a reservoir and that's it. Development and even protection are largely up to local governments with no idea of what they are supposed to do and no wherewithal to do it.
>
> [The State should provide] heavy doses of technical assistance for counties without the resources of leadership to fend for themselves or to employ (or even think of employing) private consultants.[25]

The surest method of control makes advisable outright purchase of large quantities of lands surrounding proposed reservoirs.

> The agency building the reservoirs should have authority to acquire ample land to assure capture of the public benefits from recreation . . . . resulting from the public investment. Lost to the public, [these benefits] become a windfall to private owners. Acquisition of most or all of the shoreline by the agency constructing the reservoir usually is advisable. The terrain can then be more easily studied and earmarked for its most advantageous use, without the hindrance of speculation and profiteering in land values which have been increased by a substantial public investment.[26]

There should be no legal difficulty in acquiring the necessary lands in the Meramec since Missouri statutes provide for the acquisition through eminent domain of sufficient lands around reservoirs for recreational purposes.[27]

Other controls are needed in addition to land-use controls. Ardent fishermen resent the rise of water skiing, skin diving, and motorboating as harmful to the sport. On every lake, however, there are long arms, narrow coves, and upper reaches of water that will always be more suitable for fishing than for any other activity. A system of zoning to keep these areas free of motorboats might well be installed.

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[25] Sylvan Meyer, "Influence of Metropolitan Atlanta in the Upper Chattahoochee Valley Area", Sou'easter (Publication of the Southeast Chapter, American Institute of Planners), Aug.-Sept., 1958, pp. 28-34.

[26] Tennessee Valley Authority, Outdoor Recreation for a Growing Nation, Knoxville, 1961, pp. 2, 7, 14, 15.

[27] Excess Condemnation Law, Article I, §27, Missouri Constitution.

Building permits and leases should be issued with restrictions such as those outlined in Appendix D. Group boat docks could be encouraged, leaving substantial frontage on the shore in natural condition. An architectural consultant should be retained by the administering agency to insure harmonious development. These controls will help assure maximum return to the public on the investment of public funds.

Administration

A broadly based public agency should be responsible for the coordination and development of recreation facilities at the proposed reservoir. This agency could assume one of several forms which have been used with success elsewhere. The Cook County Forest Preserve District in Illinois manages 46,000 acres for the recreational use of Chicago area residents. In the Kansas City area, a 3,400 acre park with a 1,000 acre lake has been developed by Jackson County Park Department. Each is operated by a single county. A multiple-county district, the Huron-Clinton Metropolitan Authority, provides outdoor recreation opportunities for the Detroit region. In the San Francisco area a regional agency, the East Bay Regional Park District, maintains large areas for recreation. In Ohio, the Muskingum Conservancy district operates land surrounding its reservoirs for recreational purposes.

One of these types of organizational forms could be utilized to manage the recreational development of the Meramec Basin, or a completely new form could be devised to suit the specific needs of the Meramec. Since the functions to be performed are similar to those of a city, perhaps a large area around a reservoir could become an "incorporated lake". An enlarged entity similar to the proposed Municipal County of St. Louis could likewise perform these functions. A semi-private corporation patterned after the urban redevelopment corporation might also be formed to handle the job of recreation development.[28]

A variety of administrative forms are possible. It is essential that problems of recreation administration be considered at the outset of project planning, so that the appropriate agency be in operation when needed.

[28] These proposed administrative devices are from a memorandum by Wm. Weismantel.

Financing

The ORRRC report contains several recommendations relating to financing outdoor recreation. These deserve reiteration here.

> Recommendation 12-1: State and local governments should consider general obligation and revenue bonds as a means of financing capital investments.
>
> Recommendation 12-2: State and local governments should consider new revenue-producing possibilities in developing plans for financing their recreation programs.
>
> Recommendation 12-3: Public agencies supplying outdoor recreation opportunities should adopt a system of user fees and charges.
>
> Recommendation 12-4: A Federal program of grants-in-aid should be established promptly to provide matching funds to the States to stimulate recreation planning and to assist in acquiring lands and developing facilities for public outdoor recreation.
>
> Recommendation 12-5: A Federal loan program should be established to complement the grants-in-aid program.[29]

Location

"Within limits, the location of reservoirs and artificial lakes can be deliberately planned. This offers a flexibility in distribution not paralleled by any other water recreation resource."[30] As pointed out in Volume I, maximum benefits from development of the water resources of the Meramec can be obtained by utilizing reservoir sites near St. Louis. As pointed out by the Outdoor Recreation Resources Review Commission, the usefulness of land and water resources for outdoor recreation hinges on three factors: (1) proximity to population; (2) physical and legal accessibility; and (3) suitability for recreation purposes. All three conditions can be obtained in the Meramec.

> The first task is to provide recreation for the metropolitan regions. On the face of it, this would seem an almost impossible task, for it is precisely here that land is hardest to come by and most dear. It always has been, however, and this is why there is such an imbalance today. Traditionally, State recreation programs have directed park acquisition

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[29] ORRRC, pp. 167-172

[30] ORRRC, p. 179

> to rural areas. Now that urban land costs have risen further yet, it can be argued, it is too late to shift emphasis.
>
> But the metropolitan recreation problem cannot be solved somewhere else. Additional recreation land in the faraway places is needed, but the need is far more urgent close to home. Such acquisition, furthermore, can be highly economical. Land prices are higher near built-up areas, it is true, but for good reason: that is where the people are; and in terms of user benefits $1,000-an-acre land close to people can be a better investment thatn $100-an-acre land a weekend away.[31] (emphasis added)

Land in Jefferson and St. Louis counties may be more expensive than land farther out in the basin, but in terms of benefits accruing from development, it might be the wisest allocation of funds.

The critical need for open space acquisition is on the fringes of the built-up area -- land which will become urbanized within the next 20 years and lost for recreational use unless steps are taken now to prevent this. Construction of a reservoir in the Meramec could be used as a catalyst to focus efforts on acquiring land for public use along the shoreline. Either of the proposed reservoirs nearest to St. Louis (Pacific or Byrnes Mill) would be ideal for this purpose. The opportunity will not be available long. "Outright purchase of Central Park in New York City was made in 1856 while it was still merely hilly countryside north of the city. If Central Park did not exist today, could New York City afford to dedicate an equally large tract within its boundaries for park purposes now?"[32] Or closer to home, what is the value of Forest Park in St. Louis, which at the time it was acquired may have seemed unnecessary or overambitious? Time has a way of catching up with even ambitious plans.

The recommendations of the ORRRC indicate the need to recognize recreation as a legitimate aspect of water resource development projects.

> Outdoor recreation should be considered as an important purpose of Federal multipurpose water resource developments, and thus guaranteed full consideration in the planning, design, construction, and operation of projects. Federal investments for recreation should be approved when the recreation opportunities created are an integral and harmonious element of a State or regional recreation plan . . . . This policy

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31 p. 81.

32 R. Burnell Held, Can Other Uses be Made of Agriculture's Excess Acres? Resources for the Future Reprint No. 31, Washington, 1961, p. 225.

would permit Federal construction of an impoundment primarily for recreation in areas of particular need.[33]

Present procedures do not fully take recreation needs into account, but it is likely that these procedures will be changed in the future in light of the ORRRC recommendations. It is therefore imperative not to plan projects according to the procedures and criteria used 15 years ago. Lack of foresight can result in the construction of projects suited to the needs of the 1940's, while the needs of the next 50 years go unsatisfied, or only partially satisfied.

It is now beginning to be recognized that recreation must be moved closer to the heart of water resource planning if the desire of the American people for water recreation is to be adequately fulfilled.

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[33] ORRRC, p. 181.

APPENDIX A

DISTANCE AND RECREATIONAL USE OF RESERVOIRS

Specific examples of the effect of distance from markets upon the recreational use of reservoirs are provided by the 1960 attendance figures published by the Corps of Engineers for their reservoirs. The ratio of the annual number of visitor days to the number of acres in the normal recreation pool is used as a measure of intensity of use. Of approximately 40 large reservoirs (those having a normal recreation pool of at least 10,000 acres) listed by the Corps of Engineers, only seven have an attendance-area ratio greater than 100; i.e., more than 100 annual visitor-days/acre. (See Table 5.) All seven of these reservoirs are located near large metropolitan areas. Lake Allatoona and Lake Sidney Lanier are located approximately 40 miles from Atlanta, Georgia (population 1,000,000). Tenkiller Ferry and Fort Gibson reservoirs are located approximately 50 miles from Tulsa, Oklahoma (population 500,000). Old Hickory Reservoir is located within 15 miles of Nashville, Tennessee (population 400,000). Lavon and Whitney reservoirs are located within 50 miles of the Dallas-Fort Worth, Texas area (population approximately 1,500,000). No other large lakes are located at closer distances to large metropolitan areas, and none have attendance-area ratios greater than 100 (only four other reservoirs come close to 100 -- all are located near the Dallas-Fort Worth area).

A closer look at some of the smaller reservoirs also serves to demonstrate the importance of nearness to large metropolitan areas when considering the recreational use of reservoirs. Two small reservoirs within 50 miles of the Pittsburgh metropolitan area attract large numbers of visitors in spite of their small size. Crooked Creek Reservoir, about 400 acres, registered an attendance of slightly more than a million. Tionesta Reservoir, about 500 acres, registered almost 500,000 visitor-days. No large reservoirs are located nearer to the Pittsburgh area than these two lakes. The reservoir on the west fork of Mill Creek within the Cincinnati metropolitan area,

although only 200 acres in size, registered more than 1,500,000 visitor-days in 1960. Heyburn Reservoir located about 30 miles from downtown Tulsa registered almost 500,000 visitor-days in 1960 even though it is only 1,000 acres in size and contains water which is almost always muddy. Cherry Creek Reservoir, within 20 miles of downtown Denver, Colorado, registered 400,000 visitor-days on its 900 acres in 1960, in spite of the existence of numerous other more attractive lakes at slightly greater distances. Hansen Reservoir, within the Los Angeles metropolitan area, has a normal recreation pool of only 100 acres, but registered more than 1,700,000 visitor-days in 1960. These figures show the recreation potential of even small reservoirs if they are located very close to the centers of demand -- large metropolitan areas.

Table 5

CORPS OF ENGINEERS RESERVOIRS HAVING A NORMAL POOL OF AT LEAST 10,000 ACRES

		1960 Attendance (Thousand Visitor-Days)	Size (Thousand Acres)	Visitor-Day Per Acre
Arkansas	Bull Shoals	2,580	48.7	53
	Ouachita	2,240	40.1	56
	Norfork	1,120	22.0	51
Florida	Lake Seminole	1,370	40.3	34
Georgia	Allatoona	2,520	12.0	208
	Sidney Lanier	5,120	38.9	131
Idaho	Albeni Falls	100	10.8	9
Kentucky	Lake Cumberland	3,110	50.3	77
Minnesota	Lac Qui Parle Reservoir	10	20.0	0.5
Mississippi	Arkabutla	390	10.1	39
	Enid	420	13.0	32
	Grenada	1,400	25.6	55
	Sardis	1,460	28.9	51
Missouri	Table Rock	2,410	43.1	56
Montana	Fort Peck	160	232.0	0.7
Nebraska	Harlan County Reservoir	510	13.6	40
North Dakota	Garrison	340	324.0	1
Oklahoma	Fort Gibson	3,780	19.1	199
	Texoma	6,620	91.2	72
	Tenkiller Ferry	2,280	12.5	183
Oregon	Bonneville	610	18.7	33
South Carolina	Clark Hill	3,010	61.0	49
South Dakota	Fort Randall	490	33.7	15
	Lake Traverse	20	14.0	2
	Gavins Point (Lewis & Clark)	1,500	29.6	51
	Oahe	190	313.0	0.6
Tennessee	Center Hill	1,270	18.2	70
	Dale Hollow	1,020	27.7	37
	Old Hickory	3,950	22.5	175
Texas	Dam B Reservoir	1,270	13.9	91
	Garza-Little Elm	2,280	26.4	86
	Lake O' the Pine	1,330	18.9	70
	Lavon	2,080	11.8	176
	Texarkana	1,640	29.8	55
	Whitney	3,200	14.8	216
Virginia	John Kerr	1,790	53.2	34
Washington	Lake Washington Ship Canal	1,000	25.1	40
	McNary	900	49.5	18

APPENDIX B

QUALITY OF IMPOUNDMENTS IN RELATION TO USE

There are many factors which affect the desirability of a reservoir for recreational use. Many of these are merely a matter of individual preference, but on a great number of points there is general agreement. The factors to be discussed here fall in the whole range from complete agreement to no agreement. Where there is a lack of agreement, this will generally be noted.

Some of these factors which affect the recreational desirability of reservoirs are (1) general appearance of the shoreline, (2) size, shape, and stability of the water surface, (3) water quality, (4) depth of water and seriousness of obstruction hazards, (5) climate of the area, and (6) quality of the fishing. Many of these factors are interrelated to some degree so that the rating on the basis of one factor will affect the rating on the basis of one or more of the other factors. For example, water quality is to some degree dependent upon the depth of the water, the size of the lake; and will in turn affect the fishing quality of the lake. It is impossible, therefore, to isolate each of these factors in a discussion without mention of the other factors. However, inasmuch as possible, they are discussed under the six sub-headings listed above.

Appearance and character of the shoreline

Landforms

The rating of a reservoir according to this factor is controlled by its various components; the type of landform, the type and quality of the vegetation, soil and bedrock characteristics, and the effect of the cultural or man-made landscape features. It is these physical features which add to (or detract from) the general appearance of the shoreline. This appearance is the result of the aggregate of the above factors.

The principal landform characteristics are slope and relief. Greater slope and relief add to the visual appearance of a reservoir, but often make it more difficult

to utilize the reservoir for recreational purposes. Usually, although not always, a high degree of slope and large relief go together. These characteristics tend to make a reservoir more attractive. For example, Granby reservoir in Colorado or any of the Ozark lakes are more attractive than lakes in the Great Plains or in the flat farming country of the Midwest (Lake Texoma, for example). Where large fluctuations in reservoir level occur, steep slopes are desirable to minimize the problems generated by this fluctuation. If the slope is steep, large vertical fluctuations in lake level will have only slight effect upon the horizontal location of the lake shore. However, steep slopes render the construction of recreation facilities, particularly buildings, more difficult. With steep slopes, access to the lake is also more of a problem. These effects are offset somewhat by the better vistas afforded from high sloping land, but apparently the effect is not great enough to compensate for the other problems. A TVA study has established that fairly level land can command higher prices -- at least land bordering reservoirs with relatively stable (non-fluctuating) water surfaces.[1]

Reservoirs in the Meramec Basin would compare favorably with most other reservoirs on the basis of the landform characteristics of their shorelines. Except for the Bourbeuse River drainage area and that part of the Salem plateau drained by the Dry Fork between the cities of Salem and Rolla, all reservoir sites are located in fairly hilly land (and even the Salem and Bourbeuse areas are preferable to northern Missouri and Illinois on this count). The relatively steep slopes found in these sections would tend to minimize the effect of reservoir fluctuation which must occur if benefits are to be claimed for flood control and/or navigation.

Soil and bedrock

The soil and bedrock formations of the land along a reservoir shoreline will have some influence upon the character of the reservoir shoreline. Clay soil is likely to result in a muddy shoreline, whereas sandstone or sandy soil will probably result in a shoreline with sandy beaches. The soil and bedrock foundation of the Meramec Basin will probably give rise to a stony shoreline consisting of medium-sized rock along most of its length with a few sections of muddy shoreline along

[1] See forthcoming study by Jack Knitch, Tennessee Valley Authority.

the more level parts. While this is not as ideal as a sandy shoreline, it is far more desirable than a predominantly muddy one. The possibility also exists that there would be some sandy shoreline if a reservoir were built covering one of the few areas in the basin where sandstone comprises the bedrock. (A major outcrop of sandstone occurs along the Pacific-Crystal City axis.) The towering limestone bluffs which are characteristic of the rivers of the Meramec Basin would also contribute to the scenic character of the reservoir shoreline where they were not completely submerged by the reservoir.

Vegetation

Vegetation is also very important in determining the scenic quality of a reservoir. Contrast, for example, the treeless character of many of the Great Plains reservoirs with that of Lake Ouachita in Arkansas where one finds pine trees, deciduous trees, and grassy pastures intermingled. A tentative scale of vegetational desirability might be set up as follows: (beginning with the most desirable)

(1) Mixed evergreen trees, deciduous trees, and open land (grassland or cropland).
(2) Evergreen trees and open land.
(3) Deciduous trees and open land.
(4) Evergreen trees and deciduous trees.
(5) Evergreen trees.
(6) Deciduous trees.
(7) Grassland or cropland.
(8) Barren soil (no vegetation).

The gap between categories 6 and 7 is probably larger than the gap between any of the other categories.

The Meramec Basin contains a variety of vegetational forms but in general does not have large numbers of evergreen trees. Reservoirs located in the central or south central parts of the basin would fall generally into category 6 (solid deciduous forests), with perhaps a few areas of category 4 (mixed evergreen and deciduous forests) where pine trees become numerous enough. Most other parts of the basin would fall into category 3 (deciduous forest and open land). Along some parts of

the lower Big River, juniper (cedar) trees become numerous enough to justify a category 1 rating (mixed evergreen forest, deciduous forest, and open land) although this type of evergreen tree is probably not in the same class as pine trees. From the standpoint of the scenic quality of the vegetation this section of the lower Big River would probably attain a fairly high rating, with the rest of the basin not far behind.

Cultural features

Cultural features of the landscape can either add to or detract from its appearance. A reconstructed colonial or frontier village overlooking the lake would be a definite asset. Well-designed and constructed public or private recreation facilities would likewise be an asset. However, uncontrolled commercial or private facilities could tend to reduce the value of a reservoir for recreation because of their unsightliness. Two contrasting examples from the state of Ohio serve to illustrate the difference between controlled and uncontrolled developments. At Buckeye Lake near Columbus unplanned development has resulted in a hodge-podge of closely spaced houses (many of them poorly maintained) immediately adjacent to a noisy amusement park. Less than 100 miles away, by way of contrast, the structures along the shoreline of Leesville reservoir (one of the Muskingum reservoirs) blend into the shoreline because of the stipulation that only certain colors and finishes may be used on the outsides and roofs of these structures. As a result these structures blend into the background of the shoreline and do not intrude upon the consciousness of other lake users.

Physical characteristics of the lake

Reservoir size

The size of a reservoir is important for some types of activities; unimportant for others. Obviously, a larger-sized reservoir can accommodate more recreationists than a small one. However, the aspect under consideration here is the size of a single reservoir. In other words, is there any advantage to having a single reservoir of 20,000 acres rather than 200 reservoirs of 100 acres each? As mentioned previously, the answer depends upon the activities under consideration. For motorboating

and water skiing large expanses of water are necessary. However, even for these activities, there is probably a size above which any increases are irrelevant. Motorboaters in particular often like to be able to take long trips and explore numerous inlets along a large lake. Size is also of some importance to people who make only visual use of the lake (campers, picnickers, sightseers). Here again, there is undoubtedly an upper limit beyond which additional increases are irrelevant. Sites are available in the Meramec for reservoirs ranging from a few acres to almost 100,000 acres.

Reservoir shape

The shape of a reservoir is not one of its most important characteristics, but is of some concern in several types of recreation activity. The broad, flat, open type of lake is preferred by sailboaters because of the unobstructed breezes it affords and by water skiers because of the greater maneuvering room afforded them. The narrower, more winding type of lake is preferred by most users who are interested only in the scenic quality of the lake. Motorboaters are divided on the subject -- some preferring the large open lake for speedboating, others preferring the winding type of lake for the scenic vistas it affords. Most potential Meramec reservoirs are of the latter type. (The size of a lake is usually available and is given in acres. The shape of a lake cannot easily be reduced to a single statistic. However, some idea of the shape of a lake can be derived from a comparison of the size of a lake and the length of its shoreline.)

Stability of reservoir surface

The importance of stability of the lake surface (the amount of fluctuation) depends upon the degree to which each activity is associated with the shoreline. Swimming is very much a shoreline activity and is therefore affected to a greater degree than most other activities. Lake fishing from the shore is affected to a lesser degree. Fishing from boats, motorboating, and water skiing are affected only insofar as the maintenance of boat launching facilities becomes more difficult and expensive with increased fluctuation. Other activities would be affected only if the fluctuation had a detrimental effect upon the appearance of the vegetation along the shoreline.

(A more detailed analysis of the effects of reservoir fluctuation is contained in a separate appendix to this chapter.)

Depth of water

The depth of a lake is not in itself one of the more important factors. It does, however, have an effect on other factors. For example, it affects the turbidity and temperature of the water and its potential for fishing. A certain minimum depth is required for water skiing and boating, but once these few feet of depth are obtained, depth of water is not critical. (If use of the more shallow portions of a proposed reservoir for motorboating and water skiing is anticipated, it is necessary that greater care be exercised in removal of tree stumps and other obstructions from these shallow sections.) Depth of water is very important with regard to a sport which is becoming increasingly popular -- skin diving. Both water clarity and water depth are desirable for this activity.

Water quality

Another important factor affecting reservoir attractiveness is water quality. The most important measures of water quality for recreational purposes are (1) turbidity, (2) sanitary or bacteriological water quality, and (3) temperature.

Turbidity

Turbidity, although not necessarily the most important factor, has an effect upon a greater number of activities. Since muddy water is noticeable from a great distance, it affects not only those activities which involve direct physical contact with the water, but also those whose only contact is visual. While the primary effect of turbidity will be felt by those activities such as boating, water skiing, and swimming (which require close contact with the water), some effect will also be noticeable on camping, picnicking, and sight-seeing.

Sanitary quality and temperature

Sanitary water quality and temperature of the lake water influence only those activities in which the recreationist is in actual physical contact with the water.

However, its effect on these activities is very great. Water skiing and swimming may be completely ruled out if the water temperature is too low or if the water is polluted. Fishing is also greatly affected by these two factors. Water pollution can greatly damage or even completely eliminate the fishing potential of a reservoir. Changes in water temperature can also effect great changes in the character of the fishery resource. At Lake Taneycomo in southern Missouri, for example, warm water species of lake fish have given way to cold water species (trout) when the release of cold water from the newly completed Table Rock Lake upstream effected a change in water temperature. At the same time water skiing has decreased, and swimming in the lake has been greatly reduced (most resorts on Lake Taneycomo have found it necessary to construct swimming pools for the use of their guests because the lake water is too cold for comfortable swimming). Both natural and man-made lakes have had their recreation potential reduced by pollution. Beaches along parts of the Great Lakes have been closed because of pollution. In the Muskingum Valley, plans for a recreation pool behind Dover Dam on the Tuscarawas River were abandoned because of wastes discharged into the river by cities upstream.

Fishing

The fishing quality of a lake is rather difficult to define. It is represented by such statistics as the rate of catch, the size of catch, the species composition of the catch, and other factors. It is important to only one activity -- fishing. It is not necessarily linked to other factors: for instance, even if a reservoir were highly rated on each of the other factors affecting recreation use but a poor reservoir for fishing, its use by fishermen would probably be limited. (The fishing quality of a reservoir would probably have some effect also on skin diving.)

Climate

Climate is another factor which affects recreational use of a reservoir. It ranks with turbidity in the number of activities affected. A reasonably mild temperature is required for most water-based activities. Those activities requiring

physical contact with the water (water skiing and swimming) are greatly affected by temperature. Activities which take place primarily out of doors are likewise greatly affected (camping, picnicking, and boating). Motorboaters can insulate themselves somewhat from the cold temperatures, depending upon the type of boat. Again, fishermen seem less susceptible to the conditions of precipitation than do other recreationists with a similar degree of protection from the elements.

The climate of the St. Louis area is ideally suited for most types of water-based activity during three or four months of the year. The weather during the summer months is warm and reasonably clear. This summer recreation season is preceded and followed by a period of one or two months during which weather conditions are generally suitable for some kind of outdoor recreation activity. There is only a period of approximately four months during the winter when conditions are such as to discourage most types of outdoor recreation.

Accessibility

An additional factor affecting the recreational desirability of a reservoir, but somewhat in a class by itself, is accessibility. It is a factor which is influenced by natural factors but is controlled by human factors. The term accessibility is used to refer to two slightly different factors. One is the distance in terms of miles or minutes from major centers of demand to the reservoir area. The other use of the term refers to the degree of difficulty of obtaining access to different parts of the reservoir and its shoreline. Obviously both are important to the recreational use of a lake, and they affect all types of recreation activities.

Summary

A summary of the effects of these various factors on different types of activities in tabular form is presented in Table 6. The previous discussion has been on a factor-by-factor basis. The review which follows is on an activity-by-activity basis.

Other boating is affected by the four shoreline factors, by reservoir shape, by turbidity, and by climate. Motorboating is likewise affected by the four shoreline

Table 6

EFFECT OF PHYSICAL FACTORS ON VARIOUS RECREATION ACTIVITIES

	SHORELINE CHARACTERISTICS				PHYSICAL LAKE CHARACTERISTICS				WATER QUALITY			OTHER		
	Landforms	Soil & Rock	Vegetation	Cultural	Size	Shape	Stability	Depth of Water	Turbidity	Sanitary	Temperature	Climate	Fishing Quality	Accessibility
Other Boating	X	x	X	X	x	x			X	x				X
Motorboating	X		X	X	X	x		x	X	x		x		X
Water Skiing					X	X		x	X	X	X	X		X
Swimming	x	X	x				X	x	X	X	X	X		X
Fishing							x	x	x	X	X	x	X	X
Camping	X	X	X	X	x	x			x			X		X
Picnicking	X	X	X	X	x	x			x			X		X
Sightseeing & Relaxing	X	X	X	X	x	x			x			x		X
Skin Diving								X	X	X	X	X	x	X

X Very important
x Moderately important
Unimportant

characteristics. It is likewise affected by the size of the reservoir, and to a lesser degree by its shape and depth. Turbidity of the water is quite important, and climate is of some importance. Water skiing is greatly influenced by the size and shape of a reservoir and to some extent by its depth. It is also greatly affected by the three measures of water quality and by climate.

Swimming is affected by the soil and bedrock characteristics of the shoreline and to a lesser extent by the landforms and vegetation. It is very greatly affected by the stability of the water level and the depth of the water. All three measures of water quality are of great importance, as is climate.

Fishing is somewhat affected by reservoir stability, depth, turbidity, and by climate. It is affected to a greater degree by the sanitary quality of the water, water temperature, and of course, by the fishing quality.

Camping is most affected by the four shoreline characteristics and by climate. It is affected to a lesser degree by the size and shape of the reservoir and the turbidity of its water. Picnicking is affected by the same factors as camping, and to roughly the same degree. Sightseeing and relaxing are also affected by the same factors, and approximately to the same degree (except that climate is of less importance).

Skin diving is affected to a slight degree by the fishing quality, and to a greater degree by the depth of the water, the climate, and the three measures of water quality.

Meramec reservoirs would rate well on most aspects of reservoir quality. Shoreline characteristics would be quite good. Sites are available which allow good physical lake characteristics, but care must be taken to insure that use of reservoirs for multiple purposes does not adversely affect reservoir stability (shoreline fluctuation). Water quality in a Meramec reservoir would be above average. Fishing quality should also be good, and the climatic characteristics of the area would assure a fairly long recreation season. The factor of accessibility is of considerable importance, and it is here that Meramec reservoirs would be most highly rated.

However, even within the Meramec there are sizable differences in accessibility. Reservoirs nearer St. Louis would provide benefits to a larger number of persons and are therefore preferable to more distant ones.

APPENDIX C

RECREATIONAL VALUE OF RESERVOIRS AT VARIOUS LOCATIONS IN THE MERAMEC BASIN

The optimum location of a reservoir primarily for recreational purposes will reflect the interaction of a number of often conflicting factors. Probably the most important of these is proximity to a large number of potential users. Other factors include the scenic quality of the landscape and the quality of impounded water. The relative desirability of these factors must be balanced against the amount of benefits to be derived from other multiple purposes and the costs involved in constructing a reservoir at a particular site.

What follows is a very general discussion of possible reservoir sites in the Meramec Basin with primary attention to their recreational value, and secondary attention to other possible benefits. The analysis is not made on the basis of precise data, but only on rough estimates of the importance of these various factors. The potential reservoir sites are considered in ascending upstream order.

<u>Sites on the lower Meramec River</u>

Several potential sites exist in the lower Meramec Basin (that is, on the Meramec River below its confluence with the Big River). In this area there are three likely dam sites which could be used to create lakes extending above the confluence of the Meramec and Bourbeuse Rivers and on the Big River to a point above Morse Mill. The first site, near Fenton, would create a lake which would have the advantages of being a large lake, in fairly scenic country, and as close to the St. Louis Metropolitan Area as is possible. Unfortunately, it suffers from the disadvantage of being very expensive to construct. Within the areas to be inundated by this lake are the cities of Valley Park, Times Beach, and Pacific; the $50,000,000 Chrysler assembly plant; more than ten miles of the main line of the Missouri Pacific and the Frisco Railroads; as well as several miles of the recently completed interstate highway. The replacement costs of these facilities result in unduly large costs for the project.

Another site exists several miles upstream at Lincoln Beach. Although located somewhat farther from the heart of the St. Louis urbanized area, it would possess sizable recreation potential. It would have the advantage of sparing the city of Valley Park and the Chrysler assembly plant from inundation, and would avoid most

of the relocation of Interstate Route 44. However, it would require railroad relocations as extensive as those of the previously described reservoir. Again, these costs are likely to prove excessive when compared to the costs of other possible locations.

A third lower-basin site is located just above Times Beach. In nearness to the St. Louis Metropolitan Area, it is comparable to the previously described location. A dam at this location would have the advantage of dislocating only one major town, Pacific, requiring no relocation of the interstate highway, and less relocation of the railroads than the preceding two reservoirs. Its scenic characteristics and the quality of its water should be little different from the previously described reservoirs. In terms of accessibility it rates somewhat below the Fenton reservoir, but very similar to the Lincoln Beach reservoir. All three of these reservoirs would have less clear water than some upper basin reservoirs because they would receive water from both the Bourbeuse River and the Big River in addition to the Meramec River. These reservoirs would have advantages over upper basin reservoirs in the ease with which regulation of shoreline uses can be achieved. Parts of these reservoirs would be in St. Louis County, which has an active Planning Commission equipped to perform such zoning as would be needed. The other parts of the lake would be in Jefferson and Franklin counties, both of which are probably more aware of the need for planning and zoning regulations than would be the case in upper basin counties.

Reservoirs in the lower basin would possess certain advantages in reference to otherbenefits to be obtained from water resource development. The reservoir formed by a dam near Times Beach (Lake Pacific) could do an efficient job of flood control in the lower Meramec because of its location just above the primary flood damage centers. The other two reservoirs would probably flood out as much or more usable property as they would protect in the Meramec. All three reservoirs would be most useful for Mississippi River flood protection. All three would likewise be ideally suited for Mississippi River navigation benefits. Because of the large surface area and the relatively steep shoreline, a great deal of storage would be available

without large lateral fluctuations in the reservoir shoreline. If hydroelectric power should prove feasible, these dams would be well located with regard to the demand for electric power. Water supply benefits in the Meramec Basin are likely to be limited to supplying water to potentially deficient areas in northern Jefferson County and southern St. Louis County. These three reservoirs would be ideally situated to satisfy any demand for the municipal and industrial water from this area.

Sites on the lower Big River

The next most desirable group of reservoir sites with regard to their recreational value is found on the lower Big River. The most promising sites in this reach are one at mile 0.5 above the mouth of the base (Byrnes Mill Reservoir), one near Cedar Hill, and one above Morse Mill.

The site near the mouth of the Big River offers the most in terms of accessibility to St. Louis recreationists. A dam at this location would result in a wide, attractive lake and would cause a minimum of disruption to settlements and lines of communication; no railroads or major roads would be affected. In most aspects it would be similar to the Times Beach reservoir, but would be only one-third to one-half the size. It would have the advantage of causing less dislocation, but would have the disadvantage of storing less water per dollar invested.

The Cedar Hill reservoir would be similar in most respects, but would cause less dislocation since it is located above the town of Cedar Hill. Therefore, it would affect only Morse Mill. The Cedar Hill reservoir would also be somewhat less accessible to St. Louis recreationists.

A reservoir located above Morse Mill would cause practically no dislocation. However, it would be the least accessible of the three reservoirs on the lower Big River.

All three of these reservoirs on the lower Big River would probably have water quality similar to reservoirs on the lower Meramec River. Their contribution to flood control and navigation, however, would be considerably less because they control only about one-fourth as much drainage area as the dams on the lower Meramec.

Sites on the middle Meramec River

The next group of reservoirs in terms of accessibility are on the Meramec between the junction of the Bourbeuse River and the junction of the Big River. Water quality in this area would not be significantly different from that of the previously described reservoirs. A dam at the Robertsville location would cause parts of the city of Union to be inundated, and would require relocation of small segments of the Interstate Route 44 and the Frisco Railroad. Its value for flood control and navigation would be high, since it would control more than half of the total drainage area of the Meramec at a point just above the reaches of maximum flood damage.

Sites on the upper Meramec River

The next group of reservoirs in terms of accessibility would be those located on the Meramec River above its confluence with the Bourbeuse River. All of these sites would be easily accessible from Highway 66. All would have water which is considerably clearer than any of those sites previously mentioned (because they would be above the sediment-laden Bourbeuse River). All of these reservoirs would be fairly useful for flood and navigation storage. However, reservoirs in this area pose a problem because of the scenic caves which are located along the river. These are presently the major scenic attractions of the Meramec region, and many would be flooded by several of the possible reservoirs in this reach, unless their capacities were limited. (The location of these caves is shown in Figure 3 of Volume II, Chapter 4.)

Another disadvantage of large reservoirs in the upper part of this area would be the flooding out of two of the most pleasant canoeing and fishing streams in the Meramec Basin -- Huzzah and Courtois Creek. The heavily wooded area which would make up the shoreline of these reservoirs would be quite attractive (although perhaps not as attractive as one interspersed with cleared areas). An additional advantage of reservoirs in this area is that part of their shoreline would be along land which is already publicly owned (Meramec State Park and Huzzah

Wildlife Area) and the acquisition of more public land by expanding these areas would probably be facilitated.

Sites on the Bourbeuse River

Another group of reservoirs might be constructed on the lower parts of the Bourbeuse River. All of the feasible sites are above the city of Union. The landscape created along these shorelines would be quite pleasant -- composed of some woodland interspersed with cultivated fields. However, because of more gentle slopes, problems arising from shoreline fluctuation would be greater. The water would be muddier than the water of any of the previously mentioned reservoirs. An additional drawback is the general opposition to large dams by the people of the Bourbeuse River area. In terms of accessibility to large numbers of recreationists these reservoirs would rank below those on the Meramec previously mentioned. The flood control and navigation potentials of reservoirs on the Bourbeuse would be less than any of those previously described for the Meramec, and would be comparable to those previously described for the Big River.

Sites on smaller streams

Two other groups of reservoirs deserve mention. One group would consist of reservoirs on the upper reaches of the Meramec, Bourbeuse, and Big Rivers; another group would consist of reservoirs on some of the smaller tributaries of these rivers in the lower basin closer to St. Louis. The latter group would have considerable recreation potential, but costs are likely to be higher than the larger reservoirs (based on dollars per unit of capacity). They would, however, offer advantages -- more flexibility of location, probably less total cost, and greater ease of zoning for specific types of use. Among the disadvantages would be their limited multi-purpose use, their high cost per acre of water surface provided, and the possibility that they would be quickly saturated by recreationists.

The other group of reservoirs, those in the upstream reaches, would have more limited utility for recreation. All would be relatively distant from the primary source of demand in the St. Louis area. They could probably take care of local

demand, however, and a number of the smaller reservoirs might be utilized for this purpose if a large reservoir were built very close to St. Louis. Several types are possible. One would be a debris or sediment dam on one of the muddier rivers such as the Bourbeuse or Dry Fork. Its purpose would be to intercept sediment to prevent it from flowing into the river and/or reservoirs downstream. Because the reservoir would remain filled with water at a fairly constant level, it would receive some recreational use. However, because of the distance from population centers and because of the muddiness of the water, this recreation use may not be large. Another type of reservoir might be built for purposes of low flow augmentation on the Huzzah or Courtois -- to maintain the streams at floatable levels for longer periods. These reservoirs could be used for recreation during the spring and early summer. At other times the reservoir would most likely be dry. Distance from potential users would also be a handicap in the recreational use of this type of reservoir.

Summary

The best location for reservoirs in the Meramec Basin in terms of usefulness for recreation is the lower Meramec River or the lower Big River. The second most desirable location is the Meramec River above its confluence with the Bourbeuse River. Reservoirs in this area would be useful for recreation, but would suffer from being considerably less accessible to the St. Louis market than the lower basin group.

Depending on the location of a major reservoir, a few smaller tributary reservoirs might be found useful to supplement the supply of recreational facilities.

APPENDIX D

SAMPLE COTTAGE SITE LEASE
(Used by the Muskingum Conservancy District)

TO HAVE AND TO HOLD said premises unto the Lessee for the term of one (1) year from the .... day of ...., 19................., unless sooner terminated as provided herein, together with the right of access to the waters of .... Reservoir at an approved point and to use said waters for fishing, boating, skating and other approved sports, in accordance with the rules and regulations of the District and the Division of Wildlife and the right to construct an approved boat dock at the said point of access, and upon the payment of all admission and license fees, the right to place not more than two (2) boats on said waters at said point for the use of himself, members of his family and his guests; subject, however, to the following:

(1) Any flood easement that may have been or that may hereafter be conveyed by the District to the United States of America;

(2) An Agreement of Lease between the District and the State of Ohio dated September 5, 1958, for a period commencing July 1, 1961 and ending June 30, 1986, with option of renewal.

This lease and the rights of the Lessee hereunder shall also be subject to all future modifications, renewals and/or extensions of said agreement of lease between the District and the State of Ohio, upon the same or modified terms, as well as any future agreement or agreements replacing said existing agreement of lease, and Lessee by .... acceptance of this lease covenants and agrees not to prevent or interfere with public use of areas designated for public use in said agreement of lease and any present or future modifications, extensions or renewals thereof, or future agreement or agreements replacing said agreement of lease.

(3) All existing oil and gas leases and utility rights-of-way thereunto pertaining;

(4) The right of the District and, or the United States to maintain and operate the .... Dam and Reservoir in accordance with the Official Plan of the District, said District and the United States not to be liable for damages of any kind to the property of the Lessee located upon said premises or used in connection with the rights granted under this lease resulting from the operation of said Dam and Reservoir or from any other structure owned, constructed, operated or maintained by said District or the United States.

Yielding and paying therefor during said term, at the office of the District, an annual rental of ....Dollars ($.......................), in .... payments to be made as follows:

....

Any such rentals, or installments thereof, that are due and unpaid shall bear interest at the rate of four (4) per cent per annum until paid, and such rentals including interest, shall be a lien on any structures or other property of the Lessee, located on said premises until such rentals and interest have been paid.

II. The Lessee hereby covenants with the District as follows:

(1) To pay the rent reserved on the days and in the manner aforesaid.

(2) To save the District free and harmless from the payment of any taxes levied on said premises that are based upon a tax valuation for the premises in excess of the tax valuation at the time of the execution of this lease and any taxes or assessments levied against said premises because of change in use from the uses prior to this lease, to the uses provided for in this lease, or because of any improvements erected thereon.

(3) That unless he notifies the District in writing not less than thirty (30) days prior to the expiration of this lease, or the expiration of any yearly renewal and extension to it, he shall be deemed to have exercised the option granted by the District under Section (2) of its agreements to have the lease renewed and extended for a period of one (1) year.

(4) To use said premises solely for residential and recreational purposes for himself, the members of his family and his guests, and not to use said premises for business purposes of any character whatsoever; and not to harbor any livestock on said premises without the written consent of the District.

(5) Not to use or permit the use of said premises, or any rights granted under this lease, in connection with or for the commercialization of any lands not owned by the District.

(6) To submit all plans and specifications for all buildings, improvements, alterations, docks and other structures, and for landscaping work, to the Engineer for approval before they are constructed, which plans shall include the color of paint to be used on the outside of buildings and structures.

(7) To keep said buildings, improvements and structures free from all liens, charges and encumbrances, except such as may be first approved by the Board of Directors in writing and to bear, pay and discharge all taxes which may be levied against the same, and save the District against any such liens, charges, encumbrances and taxes.

(8) To construct or place no cottage or dwelling house on said premises costing less than .... Dollars

($..........................) and to maintain not more than one (1) such cottage or dwelling thereon, nor more than one (1) one-car or two-car garage.

(9) To erect no buildings below elevation .... feet above sea level.

(10) To keep all buildings and other structures on said premises in a satisfactory condition of repair and appearance. To make no alteration in the external elevation or architectural design of the buildings on the demised premises, or injure or remove any of the principal walls or timbers thereof, without the consent in writing of the Board.

(11) To permit the District, its agents, and its tenants having leases with the District similar to this lease, to use the right-of-way for ingress and egress granted herein. To repair any and all damages caused by him, or other parties using said premises under this lease, to any roadways on said right-of-way, it being understood that the Lessee shall have the right to enter into agreements with other leaseholders for the construction and maintenance of such roadways. Not to require the District to maintain roadways on said right-of-way, provided the District shall repair any and all damages caused to said roadways from the use of said right-of-way by its agents.

(12) To keep without expense to the District, said premises in a clean, sanitary and presentable condition, and by approved methods remove from District property or destroy all waste, refuse, garbage and debris resulting from the use of said premises and the rights granted herein. To do or permit nothing to be done which may in any way pollute the waters of the District, and to meet, comply with and abide by the rules and regulations of the State Board of Health with respect to sanitation as far as they are applicable to said premises, lands and waters of the District.

(13) Not to use said premises for any illegal or immoral purposes, not to commit any disorderly, boisterous or indecent act on lands or waters owned or controlled by the District; not to permit or suffer any nuisance on said premises nor permit said premises to be used in any way or for any purpose that might endanger the health or unreasonably disturb the peace or quiet of persons occupying other lands of the District; not to do any act or thing to encourage the excessive use of intoxicating drugs, liquor or beer on any lands owned or controlled by the District, and not to permit any intoxicated person to enter or remain on said premises.

(14) To observe at all times and comply with and cause the members of his family and his guests to observe and comply with all laws, ordinances, rules and regulations in any manner affecting his operations under this lease, and protect the District against any claim or liability arising from or based upon the violation of any such law, ordinance, rule or regulation whether by himself or members of his family or his guests.

(15) Not to cut, shoot at, bark or otherwise damage or destroy any standing trees of any size or shrubs on District lands, except by permission of the Engineer, and to do nothing upon the lands and waters owned or controlled by the District that will mar the natural beauty of the same. Not to destroy or in any manner interfere with nests and other habitat of birds.

(16) To take special precaution with respect to fires by not carelessly dropping or throwing about burning matches, hot ashes, smoking materials, or any inflammables; not to build on District land any bonfires, or other fires except by permission of Division of Forestry, State of Ohio; and to construct and maintain all chimneys, fireplaces and other fire containers so as to minimize danger of such fires from sparks.

(17) To permit the District to use a right-of-way along the rear line of said premises and three feet therefrom for the purpose of erecting or laying electric light or telephone pole lines and conduits, and water lines, with the right to go upon said right-of-way for the purpose of erecting, maintaining, repairing, and removing said lines, with the understanding that said right-of-way must be so used as to interfere as little as possible with the use of the premises by the Lessee.

(18) To permit the District to enter said premises and summarily abate and remove any erection, thing or condition that may be or exists thereon, contrary to the intent and meaning of the provisions of this lease, and it shall not, by reason thereof, be deemed guilty of any manner of trespass for such entry, abatement or removal. If the Lessee shall fail to maintain buildings and other structures or repair damages in accordance with the provisions of this lease, and upon notice of such failure given by the Board shall not provide satisfactory maintenance and repairs within (30) days after delivery of such notice, then the District may either cause such materials to be furnished and work to be done as may be necessary to provide such satisfactory maintenance and repairs, and the entire cost thereof, including a proper proportion of administrative and overhead expenses, shall be paid by the Lessee, and such costs shall be a lien on any structure or other property of the Lessee located on said premises and no buildings or structures shall be removed by the Lessee under Section (3) of the District's agreements until such costs have been paid, or the District may proceed as provided under Part IV herein, at the election of the Board.

(19) To be responsible for the acts of any of the members of his family, his guests, or other persons occupying said premises or using the same or any of the rights granted under this lease, and the violations of any of the provisions of this lease by any such persons during such occupancy or use shall be considered the same as though violated by the Lessee himself and may be cause for the cancellation of this lease.

(20) To promptly report to the proper officers all violations of law and the rules and regulations of the District and the Division of Natural Resources.

(21) Not to assign, transfer, sublet or otherwise dispose of this lease or any part thereof, without the previous consent of the Board, in writing.

(22) To yield up the demised premises at the termination of this lease, or any renewal thereof, in as good order and condition as the same now are or may be put by the District, reasonable use and wear and damage by fire and other unavoidable casualties excepted.

III. And the District hereby covenants with the Lessee as follows:

(1) That the Lessee paying the rent hereby reserved and observing and performing the several covenants and stipulations herein on its part contained, shall peaceably hold and enjoy the demised premises during the said term without any interruption by the District or any person rightfully claiming under it, except as hereinbefore provided.

(2) That the Lessee shall have the right and option to have this lease renewed and extended from year to year for periods of one (1) year until a date fourteen (14) years from the beginning of this lease, and the Lessee shall have the first preferential right and option to enter into a new lease agreement at the expiration of the 14-year period, which new lease shall be similar in nature and form, but with such revision of rentals, terms and other conditions as the Board may deem necessary; and the Lessee shall have the right to similarly enter into a new lease agreement at the end of each subsequent 14-year period, provided that in all cases all of the covenants and agreements of the Lessee shall have been fully performed as herein stipulated, and provided further that this lease will not be renewed beyond a date five (5) years from the beginning of this lease, unless at the end of the five (5) years the Lessee shall have erected and is maintaining an approved cottage or dwelling house on the premises with a cost as provided herein.

(3) In event this lease, by exercise of the option for year to year renewal hereinbefore provided, continues in effect for more than seven (7) years, the yearly rental for the years subsequent to the seventh year shall be subject to adjustment and change as herein provided. In determining whether a change shall be made in the annual rental at the end of the first seven years, the "Index of Change in Prices of Goods and Services Purchased by City-Wage Earner and Clerical-Worker Families to Maintain Their Level of Living" issued monthly by the U. S. Bureau of Labor Statistics, which index is commonly called the "Revised Consumers Price Index" or "BLS Cost-of-Living Index", shall be used

as a standard. If the said index figure for the month of January .... shows either a rise or fall from the index

figure for the month of January ...., the annual rental payable under the terms of this lease for the years beginning with the eighth year the lease is in effect shall be correspondingly increased or decreased to the nearest dollar

figure by the percentage difference representing the increase or decrease of the January .... index figure as com-

pared to the January .... figure. In event such presently issued monthly index should be discontinued or a new or revised one substituted therefor by the Bureau of Labor Statistics or other agency of the United States, such new or revised or other similar index as is generally accepted as a substitute shall be used for the purpose of computations under this lease, with such conversion factor or other device as shall be generally recognized and adopted in connection with contracts based on such index.

(4) That any buildings erected by the Lessee on said premises shall be the property of the Lessee, except as herein provided, and may be removed by him, provided all moneys due or to become due under the terms of this agreement shall have been paid; provided also that all liens placed upon the property covered by this lease, including said buildings, by the act or default of the Lessee shall have been satisfied whether such liens have been made with the approval of the District or otherwise; provided also that said buildings are removed within thirty (30) days after the termination of this lease for any cause; provided also that the removal is done in an approved manner that will not cause damage to any property of the District and will leave the premises in a neat and orderly condition; and provided further that before said buildings are removed the Lessee shall furnish surety bond in such form and in such amount as will be satisfactory to the Board conditioned upon the removal being made in a satisfactory manner.

(5) All cottage site leases are subject to the same general restrictions and reservations contained in this lease.

IV. Provided, always, and these presents are upon this condition, that if the rent reserved or any part thereof shall be unpaid, or if at any time any of the covenants and agreements on the Lessee's part herein contained shall not be performed or observed, the Board shall have full right to demand immediate payment in full of all payments due or to become due under the terms of this lease, and shall have full right to use every remedy provided for in this agreement and at law to collect such payments, and this lease agreement shall become void to all intents and purposes whatsoever, at the election of the Board, by mailing to the Lessee thirty (30) days' written notice thereof, and from thenceforth all right, title and interest of the Lessee in the premises described shall terminate and cease and shall revert to the District, with the full right to re-enter upon said premises, take and possess the same, together with all buildings

IV. Provided, always, and these presents are upon this condition, that if the rent reserved or any part thereof shall be due and unpaid, or if at any time any of the covenants and agreements on the Lessee's part herein contained shall not be performed or observed, the Board shall have full right to demand immediate payment in full of all payments due or to become due under the terms of this lease, and shall have full right to use every remedy provided for in this agreement and at law to collect such payments, and this lease agreement shall become void to all intents and purposes whatsoever, at the election of the Board, by mailing to the Lessee thirty (30) days' written notice thereof, and from thenceforth all right, title and interest of the Lessee in the premises described shall terminate and cease and shall revert to the District, with the full right to re-enter upon said premises, take and possess the same, together with all buildings and improvements thereon except as provided herein, in the same manner as if this lease had never been executed. Failure by the District to enforce any of the provisions of this lease shall in no event be deemed a waiver of the right to do so thereafter, or to have this lease cancelled as herein provided.